DURHAM COUNTY HOMEOWNER FERTILIZER BEHAVIORS SURVEY:

Summary and Analysis of Results

By
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For
Drew Cummings, Assistant County Manager

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IMPORTANT NOTE: READ FIRST

Dear reader,

Before you begin reading, I would like to impart a brief note about the structure of this report. The report is broken into four sections. First is the Executive Summary, which is a brief overview of the report. Second is a more lengthy discussion of the impetus for the study, methods, results and their significance. For someone wishing to go deeper than the Executive Summary, this is the section you will want to read. Third is the technical analysis of the data and more detailed explanation of the survey and analytical methodology. This section of the report is detailed and heavy in statistics and may be un-entertaining to most readers. Finally, the Appendix contains several supporting documents for the various parts of the report.

Regards,
Morgan Fleming

Executive Summary

Overview
Few homeowners know how to determine the correct amount of fertilizer to apply to the lawn, resulting in higher risk of over-application among do-it-yourself homeowners. The survey results provides strong evidence to suggest that many homeowners that apply fertilizer themselves are over-applying. While most homeowners report practicing best management practices (BMPs), misapplication due to not practicing BMPs is also a common problem. In all cases, the problems primarily seem to be knowledge-based ones and not motivation-based ones. Thus, public education may do much to correct the issues found by the survey.

Introduction
Durham County must comply with State mandated nutrient reduction rules by 2021. The rules call for reductions in nitrogen and phosphorus inputs to Falls Lake to 2006 baseline levels by 2021. Current management plans will prove costly. Residential and commercial fertilize application is not included in those current plans; however, while these areas may provide a vital, cheaper alternative for meeting the nutrient reduction targets, these sources of nutrient inputs are poorly understood. Thus, Durham County Manager's Office commissioned a survey to help fill in some of the information gaps about Durham County homeowners and their fertilizer application practices.

Background
The two key areas of interest to the County are Best Management Practices (BMPs) and fertilizer application rates. Key BMPs include sweeping impervious surfaces after application, not applying fertilizer along stream and lake banks, not applying fertilizer before heavy rainfalls, and mulching grass clippings instead of removing them from the lawn. The former three BMPs are of particular importance to follow. Even if a person applies the correct amount of fertilizer or under-applies fertilizer, they can still contribute significant amounts of nitrogen and phosphorus to local waterways if they do not practice the first three BMPs. Soil testing and liming of the lawn are two other important BMPs.

Fertilizer application rates are measured in pounds of nutrient per 1,000 square feet per year. Bags of fertilizer list nitrogen, phosphorus and potassium (NPK) contents on a percentage basis. Bags come in sizes suitable for fertilizing either 5,000 square feet or 15,000 square feet of lawn. Most lawn fertilizers have little to no phosphorus in them. Broadly speaking, 2.0 lbs of Nitrogen per 1,000 square feet of lawn per year is the correct rate of fertilizer application in North Carolina.

Methodology
1,000 single-occupancy households were surveyed from March to April of 2013. Participants were selected randomly via a double-randomization process. First, 40 areas were selected from around the county- 27 randomly and 13 not randomly. Then 25 households were randomly selected from within each area. Participants were first

contacted via mail to take the survey online and then mailed the survey in a paper format. The paper format of the survey came as a full survey and then as an abridged version of the survey that targeted important areas.

Survey questions covered frequency of practicing BMPs, whether the homeowner or a contractor fertilized the lawn, grass type, months fertilized in, fertilizer bag purchases, lawn size estimates and a brief test of participants' knowledge about lawn fertilizer. The survey was pre-tested and pre-viewed by county officials and focus groups consisting of county residents.

Key sources of error inherent in the survey methodology are recall error, self-reporting bias, estimation error, and geographical error. The survey depends heavily on participants' abilities to recall past information about relatively minor events, such as fertilizer bag purchases. It also depends heavily on their abilities to estimate the size of their lawn. BMP questions may be subject to self-reporting bias as some participants may know the 'correct' answer and modify their response accordingly so as to make their behaviors look better than they are. Finally, the survey may be geo-specially biased towards more rural parts of the county.

Findings

Both over-application and misapplication of fertilizer are areas for concern among Durham County homeowners. The best way to prevent over-application of fertilizer is to know how much one is putting down in the first place. Yet only a handful of the respondents actually got all three test questions related to application of fertilizer correct. Moreover, homeowners tend to over-estimate the size of their lawn, potentially further leading them to over-apply.

Misapplication can best be avoided by following several key best management practices. Nearly all respondents that reported fertilizing their lawn last year indicated that they had not properly followed one or more BMPs. Moreover, 75% of these respondents did not know what the term "best management practice" means. A small number of respondents appear to also be applying fertilizer during the wrong times of year for the given grass type.

Results from the survey indicate that roughly half of Durham County homeowners do not fertilize their lawns. Of the half that do, roughly half or more are do-it-yourself (DIY) homeowners while the remaining homeowners hire out contractors. Homeowners that fertilize at all tend to have higher value homes, be located in HOAs, and have in-ground sprinkler systems. Homeowners that hire contractors further tend to have smaller lots, have higher value homes than DIY homeowners, own sprinkler systems, and are older than DIY homeowners.

Respondents appear to be fertilizing at a mean rate of between 1.8 to 3.1 pounds of nitrogen per 1,000 square feet per year. Median application rates are between 1.4 to 2.4 lbs N/1,000 sqft/yr, suggesting that a few heavy over-appliers are responsible for the bulk of over-applied fertilizer in the county. Regardless of the accuracy of application

rates, one trend is clear. DIY homeowners that reported the highest application rates last year almost exclusively own lots less than 0.85 acres in size and reported purchasing large bags of fertilizer.

Conclusion

Residential fertilizer application is clearly a significant issue in Durham County. Fortunately, most of the problems appear to stem from lack of knowledge or awareness rather than lack of motivation. For example, the vast majority of respondents did not know what “best management practice” stands for, even though most people reported regularly following many common BMPs. A strong education campaign should, therefore, do much to help the problems identified by the study.

Some simple arithmetic can be used to put the size of the problem into perspective. There are somewhere more than 56,000 single-occupancy addresses in the county. If half of those homeowners fertilize their lawns, and one-quarter of those that fertilize do not sweep up afterwards, then roughly 7,000 homeowners are neglecting a very important BMP, potentially allowing fertilizer to wash straight into the storm drain. While the number “7,000” is, itself, meaningless and imprecise, it does tell us that the order of magnitude of the residential fertilizer problem is in the thousands of households inappropriately applying fertilizer in Durham County.

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GENERAL REPORT

Introduction

Meeting the nutrient pollution reductions required by the State of North Carolina through State-identified pathways will be costly to Durham County and is not guaranteed to succeed. Durham County is required by the State of North Carolina to reduce nitrogen (N) and phosphorus (P) loading to Falls Lake to 2006 levels by 2021, respectively, as well as to achieve strong reductions for Jordan Lake. The current state rules target agriculture, waste water systems (including septic systems), and impervious surfaces for nutrient reductions. However, all of these areas have either already been pushed near their limits for achievable reductions or will require large costs for marginal benefits.

Commercial and residential (non-agricultural) fertilizer application are the only areas available for achieving reductions at minimal costs. Commercial fertilizer application includes businesses property maintenance and golf courses and is being addressed separately. Currently, Durham County staff are interested in residential fertilizer applications. However, County staff have no reliable information on homeowner fertilizer application practices inside county limits.

In order to set policy and to measure progress, the County needs reliable baseline information about homeowner fertilizer application behaviors. Information is needed on who is applying fertilizer, whether they are doing it themselves or hiring a contractor, how much fertilizer is being applied to lawns, and whether or not best management practices are being followed. Due to budget constraints, the County also needs to obtain this information at minimal costs.

After discussions with the County Manager's Office, we determined that a survey of county residents would be the best means to gather the required information. The County Manager allocated $4,000 for the completion of a 1,000 household survey. The survey was run from March to May of 2013 and only targeted single-occupancy households. Participants were randomly selected from around the county and contacted by mail. Participants filled out the survey either online or on paper. The key final products of the data set include an analysis of the average homeowner's knowledge of and adherence to correct fertilizer application practices; an analysis of who is applying fertilizer in the County; and a set of maps indicating what parts of the County are most at risk from fertilizer application.

Background

Previous Research

Dr. Deanna Osmond of North Carolina State University performed a series of studies across several North Carolina communities in the late 1990's and early 2000's.The studies were run in Cary, Goldsboro, Kinston, New Bern and Greenville. All involved door-to-door sampling in urban neighborhoods. The subsequent studies found that

between 54% and 83% of homes applied fertilizer in the different communities. Mean nitrogen application rates varied between 0.5 to 3.1 lbs N/1,000 sqft/yr. While Dr. Osmond did not ask about best management practices in detail, she reported that many homeowners did not appear to sweep impervious surfaces after applying fertilizer and that soil testing was uncommon.[1] [2]

Neely Law, et al. published a similar study based in Baltimore County, Maryland in 2004.[3] Their survey of households found that between 56% and 68% of homeowners fertilize their lawns. The mean application rate for do-it-yourself (DIY) homeowners was 2.2 lbs N/1,000 sqft/yr. The study found that higher application rates were associated with newer homes. Best management practices were not covered in the study.

Best Management Practices

Best management practices (BMPs) are commonly accepted ways of mitigating the negative impacts of an activity. There are a number BMPs for lawn fertilization which County staff are interested in. Sweeping fertilizer off impervious surfaces is, perhaps, the most important of the six. Fertilizer that is misapplied to sidewalks, driveways and streets will be washed directly into storm drains and, ultimately, area streams, rivers and lakes.

Another important BMP is mulching grass when mowing. Mulching does not cause thatch, as is commonly believed, while it does help to keep nutrients in the lawn and build soil carbon content. This reduces the amount of fertilizer required by the grass over the long term. Mulching can be practiced by anyone with a lawn; thus its importance as a BMP.

Applicators should also avoid fertilizing the lawn before a major rainfall event. Fertilizer needs time to integrate into the soil and be up-taken by grass roots. Fertilizing right before it rains is a sure way to ensure that the nutrients are washed away before the soil and grass has had time to capture them. This is especially true for fertilizers that are primarily water-soluble. Consequently, two more BMPs are to use fertilizers that have a larger portion of nutrients in slow-release forms and to make several smaller applications instead of a few larger applications.

Fertilizer should never be applied within 20 feet of streams and lakes, including buffer zones. Fertilizer placed too close to a body of water can easily be washed over-

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[1] Osmond, Deanna L; Platt, Jennifer L (2000). “Characterization of Suburban Nitrogen Fertilizer and Water Use on Residential Turf in Cary, North Carolina.” *Horticultural Technology*. 10 (2): 320-325.

[2] Osmond, Deanna L; Hardy, David H (2004). “Characterization of Turf Practices in Five North Carolina Communities.” *Journal of Environmental Quality*. 33 (2): 565-575.

[3] Law, Neely L. et al (2004). “Nitrogen Input from Residential Lawn Care Practices in Suburban Watersheds in Baltimore County, MD.” *Journal of Environmental Planning and Management*. 47 (5) 737-755.

land into the water during a strong rain storm. More likely, however, the fertilizer will find its way into the water body via infiltration through the soil.

The final two BMPs are regular soil testing and regular liming of the lawn. Neither of these needs to be performed annually; however both should be done every 2 to 3 years. Soil testing will help the homeowner apply the correct amount of nutrient required by the lawn. Liming will help keep the acidity of the soil down and, thus, increase the amount of nutrients available to plant roots.

County staff cited anecdotal evidence that suggests many of these BMPs are not routinely followed inside the county. Dr. Osmond's work further supports concerns the County has about how often owners perform best management practices in their lawns.

Grass, a.k.a. "Turf"

Several varieties of grass occur in the Piedmont of North Carolina. Those varieties can be broken up into two main categories, cool season grasses and warm season grasses. Each type of grass (warm or cool) has its own fertilizer application schedule while the different varieties of grass require different fertilizer application rates.

Cool season grasses include fescue (short and tall) and Kentucky Blue grass. These grasses are "evergreen" and do most of their growing during the fall and spring. Cool season grasses should be fertilized in February/March and September/October/November. Approximately 2 pounds of nitrogen per 1,000 square feet is required per year. These grasses should *never* be fertilized in the summer, when they are dormant. Summer fertilizer applications will harm the grass while increasing nutrient pollution from the lawn.

Warm season grasses include Zoysia, Bermuda, and centipede grass. These grasses turn brown in the winter time. Warm season grasses should primarily be fertilized in April/May and July/August, depending on the variety. Nitrogen application rates also vary from 2 to 4 lbs N per 1,000 square feet per year.

Fertilizer

Fertilizer comes in two forms, dry and liquid. The dry form, itself, includes slow-release and "instant" release formulations. Most commercially available lawn fertilizers used by homeowners are of the dry form, with a mixture of instant and slow-release formulas included in the bag.

Traditionally, fertilizers are described as a ratio of nitrogen (N), phosphorus (P), and potassium (K) - N-P-K. The most familiar forms to gardeners are the 10-10-10, 13-13-13, and 17-17-17 fertilizers. The numbers indicate what percentage of the bag is available nitrogen, phosphorus or potassium. Thus, a 10 pound bag of 10-10-10 would contain 1 pound each (or 10% of the bag each) of nitrogen, phosphorus, and potassium.

Note that none of 3-in-1 bags are appropriate for use on lawns due to their high P and K content relative to nitrogen. For grass, a fertilizer with an N-P-K ratio of 4-1-2 or

3-1-2 is traditionally recommended. As a consequence, almost all grass fertilizers have a high nitrogen content, a very low phosphorus content, and a medium to low potassium content. Today, phosphorus content is actually often zero due to lawn-fertilizer-based phosphorus bans in many states in the Union. Only starter fertilizers have high P rates as grass needs extra phosphorus when it is newly planted.

Lawn fertilizers available at Lowes, Home Depot, and Walmart have a small N-P-K range. Almost all of the fertilizers have no phosphorus, with a few being between 2 and 3% P. Starter fertilizers are the exception, being roughly 25% P and only around 20% N. Weed and feed fertilizers and standard lawn fertilizers have N concentrations between 28 and 32%. Winterizers (intended for fall application on cool season grass) typically have slightly lower N concentrations. Winterizers have the highest K content while other fertilizers tend to have K contents around 6%.

Lawn fertilizer bags are typically standardized by the square footage of lawn they are meant to cover, not the weight of the bag. Usually, small bags cover 5,000 square feet and weigh between 13 and 20 lbs. Large bags cover 15,000 square feet and weigh between 42 and 50 lbs. Occasionally, 10,000 square foot bags may be provided for a specialty fertilizer, with a roughly 30 lb weight. Fertilizer application rates are typically measured in pounds per 1,000 square feet.

There are effectively 5 ways to apply fertilizer to a lawn. They include broadcast spreaders, drop spreaders, hand spreaders, spreading by hand, or spraying liquid fertilizer. Of the 5 methods, broadcast spreaders are likely the most common due to their speed and ease of use. They are, however, also the most likely to contribute to misapplication of fertilizer on impervious surfaces and riparian buffer zones. Drop spreading is easily the most accurate method as the fertilizer is only dropped along the path of the spreader. However, drop spreaders can often be slow and difficult to use (based on personal experience).

Methods

1,000 single-occupancy households were surveyed throughout March, April and early May of 2013. Houses were randomly selected through a double-randomization process. First, 27 quarter square mile areas were randomly selected from around the county along with 13 other areas selected based on specific County interests. Then, 25 households were randomly selected from each of the 40 target areas. Participants received up to four contacts. The first two contacts, one week apart, invited the participants to take the survey online. The third contact, in week 4, contained a full paper version of the survey. The final contact, in week 7, contained a partial paper version of the survey. The online version of the survey can be viewed at **sites.duke.edu/survey** while the paper versions can be found in Appendix A.

The survey was divided into four categories: fertilizer questions, septic system questions, geographic questions and demographic questions. The fertilizer questions were divided into sub-parts covering BMPs, fertilizer bag purchases, grass types, test questions, and other basic topics. The geography questions asked about the presence of different types of slope and proximity to lakes and streams. The septic system questions will not be analyzed in this report.

The survey instrument underwent peer-review, focus groups and some pre-testing before implementation. Peer-review included regular reviews by Durham County staff as well as feedback from several professors at Duke University's Nicholas School of the Environment and Sanford School of Public Policy. Pre-testing primarily involved having family, friends and County Officials take the online version of the survey to check it for programming errors. The two focus groups were held with Durham County homeowners and produced the most feedback, such as simplifying terminology and including extra options for some questions.

Four key sources of error challenge the results of the survey- recall error, self reporting bias, spatial estimation error, and geographical distribution error. Recall error pertains to a person's inability to accurately recall past actions. In this survey, it is best addressed by consistently confining the respondent to a set time frame, such as "last year." Self reporting bias is the participant's tendency to report more favorable outcomes than was actually the case, in particular where "correct" or "incorrect" behaviors are concerned (e.g. BMPs). Spatial estimation error is important to the survey's questions about lawn size and may have profound implications for any application rates estimated from the survey responses. Finally, the geospatial distribution of the survey sample may lead to some parts of the county being over-represented as compared to others.

Statistical analysis was done in Stata/IC v.11.2 while geospatial mapping was performed using Arc GIS. The Durham County Voter Registration database was used for sampling and to provide supplemental data to the statistical analysis. The Durham County Tax Parcel and Residential datasets were also used to provide additional data for analysis.

Findings

Over-Application and Misapplication

There are two ways a fertilizer applicator- be them a homeowner or a contractor- can err in applying fertilizer to a lawn. One is over-application, in which the applicator applies too much fertilizer. The other is misapplication, in which the fertilizer is applied at the wrong time or in the wrong places.

Results from the survey suggest that Durham homeowners are at risk for both over-applying and misapplying fertilizer. Only a handful of the 333 survey respondents

that answered the test questions got all three of the test questions correct, while the majority of respondents simply selected “I don’t know” for the application rate and NPK questions. Moreover, one fifth of respondents that reported DIY fertilizing their lawn last year reported doing so with generic 3-in-1 fertilizers such as 10-10-10. Homeowners also tended to over-estimate their lawn size by 65%. Finally, self reported rates for following BMPs were good but still left much room for improvement. Two-thirds of respondents complied with half or fewer of the BMPs they reported being responsible for. Fully 75% of homeowners that fertilized their lawn last year reported not knowing what the term “Best Management Practice” means.

Over-Application

The easiest way a homeowner can ensure they are not over-applying fertilizer is by checking that the rate they are applying the fertilizer at is between 1/2 and 1 pound of nitrogen per application. In order to do this, however, the homeowner needs to understand what the numbers on the bag mean and how to use them. The results from the test questions suggest that most homeowners simply are not familiar with these concepts.

Fortunately, where respondents did attempt to answer the test questions, they tended to get them correct. Even more optimistically, most people that answered the fertilizer rate question wrong chose the rate that was actually too low (applying 1/4 of the bag). Nevertheless, 80% of respondents reported that they did not know how to correctly calculate the application rate. Just looking at those respondents that reported DIY fertilizing their lawn last year, the percentage of people that reported “I don’t know” was slightly better at 66%. However, for County staff, who view knowing how to calculate the proper application rate as being an important BMP, 66% not knowing is still unacceptably high.

Before homeowners can learn to calculate the correct application rate for their lawn, they first must understand what the three numbers on the fertilizer bag represent. The NPK test question suggests this is another area that needs improvement. Only 20% of respondents understood that the the three numbers stand for percent nitrogen, phosphorus and potassium while 70% responded “I don’t know.” The “I don’t know” response rate improved for DIY fertilizer respondents again, moving to 50%. On the up-side, most respondents that got the question wrong were wrong because they confused potassium and phosphorus. Since phosphorus and potassium application rates are generally based on the nitrogen application rate anyways, explaining the bag numbers should be a low hurdle to clear. The County just needs to make sure homeowners understand that the first number on the bag is the one they need to use for calculating their fertilizer application rates.

The true-false question about adding more fertilizer making the lawn greener has the least room for improvement. 70% of DIY respondents answered the question correctly.

After a homeowner has determined how many pounds of a fertilizer they should apply per 1,000 square feet, they then need to know how many 1,000 square feet their lawn is. The lawn size estimation questions in conjunction with home visits revealed that most homeowners over estimate the size of their lawn when trying to estimate it as a percentage of lot size. This suggests that most homeowners, when purchasing and applying fertilizer, will err on the side of too much as they may think their lawn is bigger than it actually is. Precisely measuring lawn size is an arduous task; but a reliable tool for estimating lawn size could be invaluable to homeowners trying to stay within recommended limits for fertilizer application.

The type of fertilizer used is just as important as the amount of fertilizer used. Fortunately, very few homeowners reported using starter fertilizer, which is extremely high in phosphorus. This suggests that homeowners are generally only using that type of fertilizer when it is truly called for. Unfortunately, about 20% of DIY respondents reported using 10-10-10, which is not the correct NPK balance for grass. The primary danger of using 10-10-10 on a lawn is over-application of phosphorus by three to four times the recommended rate. Phosphorus is the most dangerous of the three nutrients, where waterways are concerned, as P tends to be the primary nutrient that drives algal blooms in freshwater. Homeowners need to understand what the correct fertilizer for use on the lawn is.

The final piece to ensuring that a lawn is not being over-fertilized is soil testing. Unfortunately, 85% of DIY respondents and 66% of respondents that hired contractors reported that their soil had never been tested. Without routine soil testing, it is impossible for the applicator to know if the fertilizer they are applying is having the intended effect or simply harming the grass and harming the environment.

Misapplication

Misapplication occurs when fertilizer is either applied to the wrong surface and not cleaned up or applied at the wrong time. According to the results from the BMP portion of the survey, roughly half or more of homeowners or their contractors routinely misapply fertilizer. These rates are likely an optimistic estimate as the questions were subject to self-reporting bias. In brief, homeowners may have reported what they *intended* to do rather than what they *actually* did when answering the BMP questions, resulting in a biased outcome. The actual misapplication rates may be higher.

Two things were particularly concerning about misapplication. The first is that 60% of respondents reported using broadcast spreaders for applying fertilizer. Broadcast spreaders throw fertilizer several feet to the left and the right of the spreader and are incredibly imprecise. Thus it is very easy for the user of a broadcast spreader to misapply fertilizer to a stream buffer zone or impervious surface unless that person pays careful attention to where the spreader is throwing the fertilizer. In an ideal world, everyone using a broadcast spreader would exert the extra effort to keep their fertilizer on the lawn and off the road. In the real world, unfortunately, yards are oddly shaped and human beings are prone to getting lazy. With such a large portion of the population

Figure 1.1: Months in which cool season grasses were fertilized. *(blue- correct month; black- incorrect month; orange- did not know)*

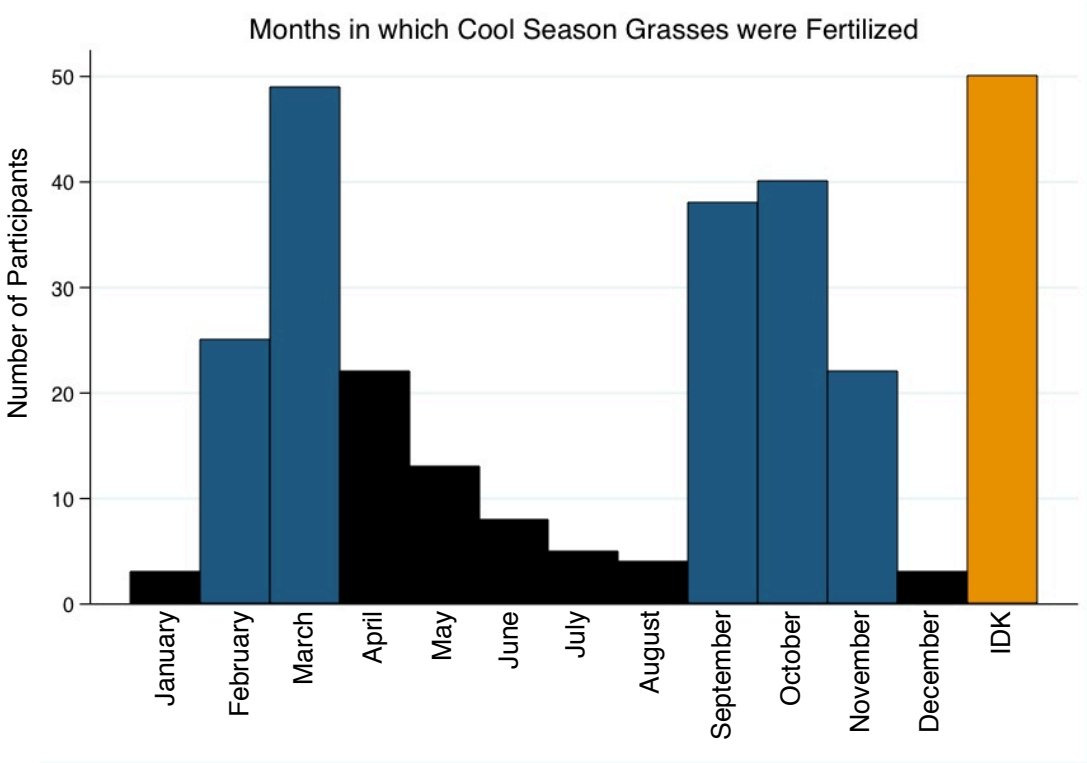
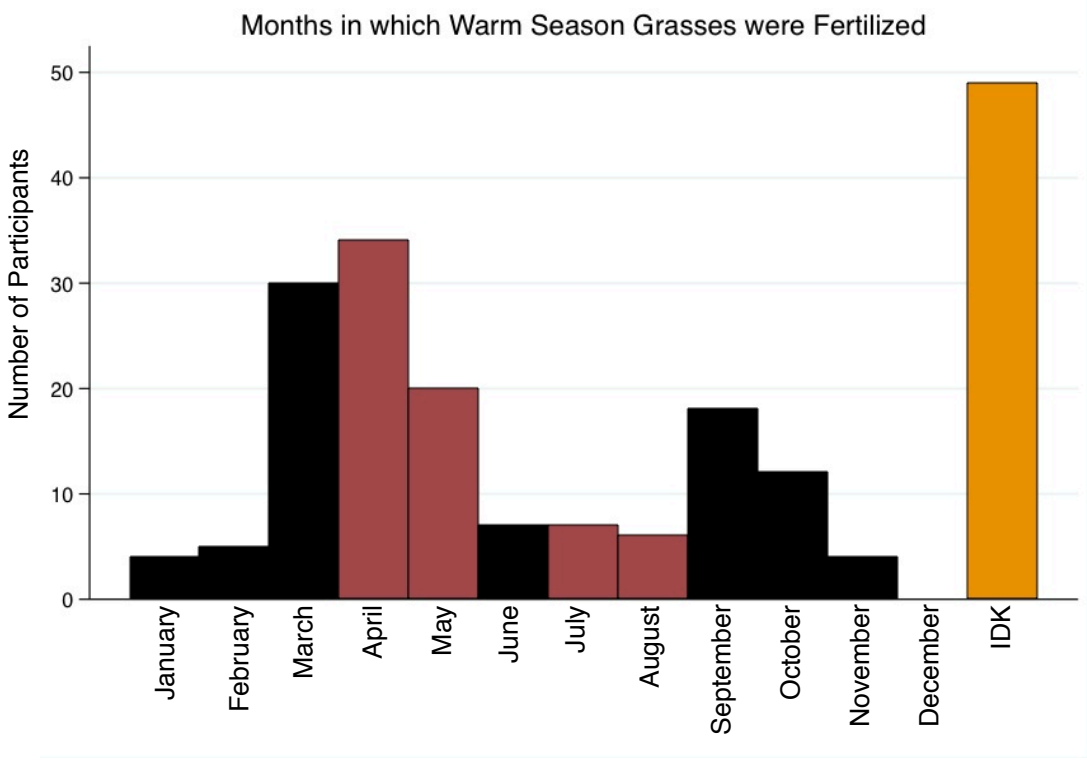


Figure 1.2: Months in which warm season grasses were fertilized. *(red- correct month; black- incorrect month; orange- did not know)*



using broadcast spreaders, it is particularly important that homeowners understand the importance and necessity of giving streams a wide berth and cleaning up sidewalks and driveways after applying fertilizer.

The second outcome from the survey that is concerning are the responses to fertilizing before it rains. Fully 10% of DIY respondents reported always applying fertilizer before a major rain event, while a further 20% reported usually doing so. Among respondents that hired contractors, no body reported that their contractor always applied before major rain events and only 8% reported that their contractor usually did so. These results suggest that a significant potion of DIY respondents think that applying fertilizer before major rain events is a good thing when it is, in fact, not.

Finally, misapplication can also occur when fertilizer is applied during the wrong time of year for the grass. For cool season grasses, this does not appear to be a major issue. Most applications occur during the correct months of the year, while a fraction of applications occur a little too late in the spring and early summer (Figure 1.1). For warm season grasses, however, the issue is greater. It appears that people are applying fertilizer to warm season grasses at roughly the same time they would cool season grasses (Figure 1.2). Thus, a more significant portion of the warm season grass applications may actually be misapplications with little benefit to the lawn. I say “may” because home visits have revealed that many lawns are actually a mix of cool and warm season grasses together- not in separate parts of the lawn.

Who is applying?

Approximately half of the respondents to the survey reported not fertilizing their lawn last year. Of those that did fertilize last year, respondents were split fairly evenly between either DIY or hiring a contractor. Subsequent modeling using results from the survey and Durham County Tax Parcel data suggests that the percentage of people not fertilizing their lawn found in the survey is indicative of Durham County as a whole. It is difficult to say whether DIY fertilizing is more common in the county, at large, than hiring a contractors is. As a final note, follow-up home visits revealed that while most homeowners that did not fertilize their lawn last year never fertilize their lawn, a meaningful portion of homeowners do fertilize their lawns on a semi-annual basis.

Statistical analysis of who is most likely to fertilize their lawn revealed an unsurprising trend. Homes with in-ground sprinkler systems in neighborhoods with homeowners associations (HOAs) and/or with high property values are more likely to have lawns that are fertilized. These three items were the best predictors of whether or not a homeowner fertilized last year. Interestingly, analysis also revealed that the larger the lot size, the less likely a homeowner is to fertilize. This trend is not strong or significant, however.

This outcome is what we would have expected to find. HOAs typically have covenants that require the maintenance of the lawn in part to maintain property value. Sprinkler systems really only have one purpose, and that is to maintain a green lawn. Finally, having an attractive lawn positively influences property value, such that

homeowners with attractive lawns have an incentive to maintain that lawn *or* homeowners that want higher property values have an incentive to repair the lawn.

Similar analysis was done to see if there was any difference between homeowners that hired contractors versus DIY homeowners. Homeowners that reported hiring contractors last year generally live in higher value homes, are older (or have lived at the address longer), have an in-ground sprinkler system and have smaller lot sizes. Living in an HOA was actually associated with being *less* likely to hire a contractor. This association was not statistically significant, however, and may simply be an artifact of the model.

These findings generally make sense. Contractors cost money and higher property values are generally associated with higher household incomes. Older persons are also more likely to value the convenience of having a contractor maintain their yard for them. In-ground sprinkler systems are statistically correlated with higher property values but are also associated with the convenience of hiring a contractor. Finally, larger yards are associated with higher costs to maintain professionally; thus, homeowners with large yards would be less likely to hire out.

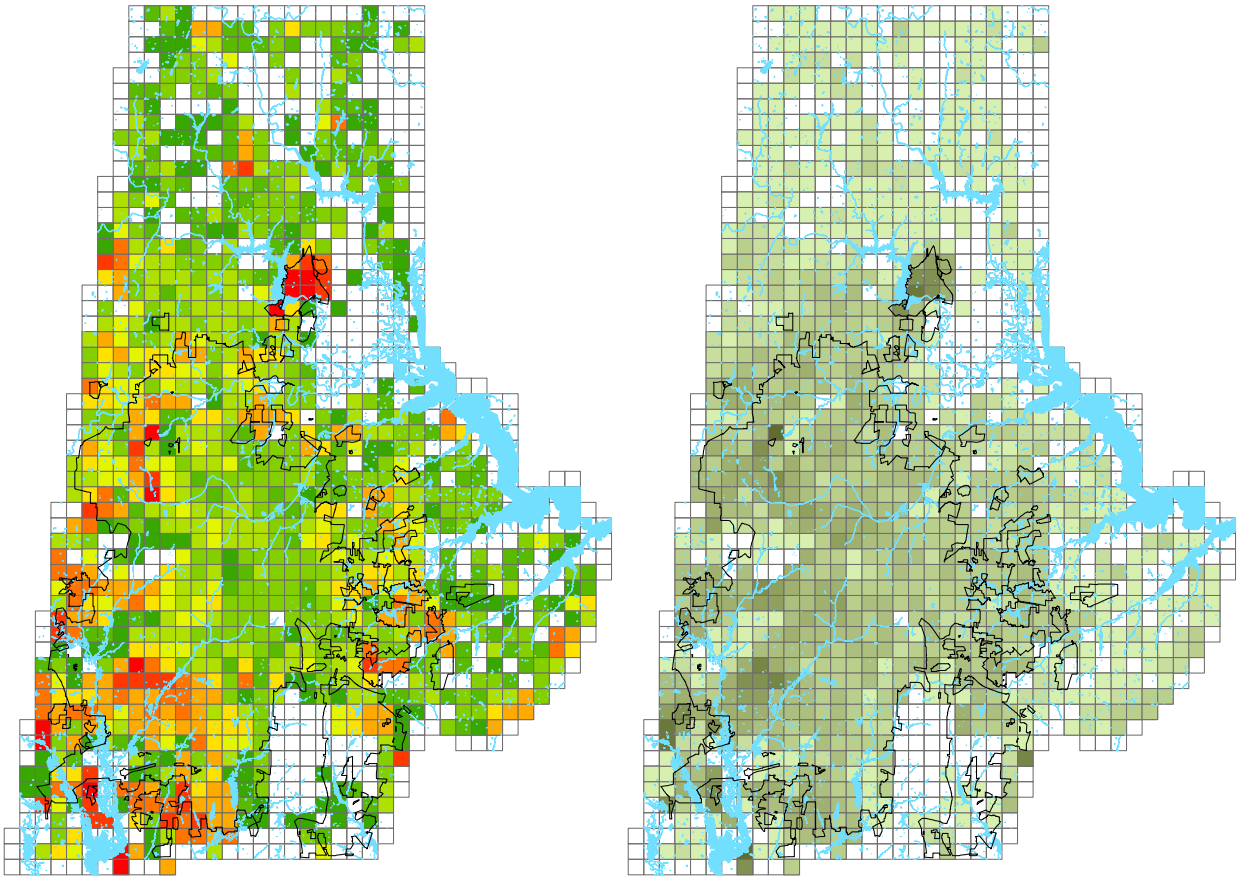
It is possible that owning a sprinkler system and hiring a contractor are both highly correlated with wanting an attractive lawn. I checked to see if homeowners with sprinkler systems valued having an attractive lawn more than homeowners without one. For all homeowners, the answer is yes. However, for the subset of homeowners that fertilized their lawn last year, the responses were inconclusive.

I was similarly curious about HOAs and lot size since smaller lot sizes are strongly correlated with living in an HOA. It could be that small lot sizes are simply masking the importance of living in an HOA to homeowners' decisions to hire a contractor. Here the data was more conclusive. Lot sizes, not living in an HOA, are the more important determinant of behavior.

As a final piece of the analysis, I generated two simple models for predicting the likelihood a homeowner fertilizes their lawn and the likelihood they hire a contractor versus do it themselves. 56,600 address from around the county that successfully matched between the county Tax Parcel database and county Voter Registration database were then run through the models and mapped. Both models used the same four predictors, mean age of registered voters at the address, total property value, lot size, and whether the home is in a neighborhood with an HOA. Unfortunately, though it is an important predictor, in-ground sprinkler systems had to be dropped due to incomplete records for the county- namely, records are only kept for inside the City of Durham.

The results can be seen in Figure 1.3. The first map illustrates what areas Durham County staff may want to focus their initial outreach work in. The second map illustrates what parts of the county may be most heavily fertilized by contractors.

Figure 1.3: Likelihood homeowners fertilize (left) and likelihood homeowners hire contractor (right).



How much is being applied?

Fertilizer application rates are highly sensitive to lawn size and, unfortunately, lawn size estimates were among the most problematic parts of the survey. Matching reported lot sizes on the survey with the lot sizes recorded in the county Tax Parcel dataset revealed that homeowners were generally pretty good about getting the size of their property right. However, spot checking lawn size estimates with actual on-site lawn measurements has revealed that respondents were not able to provide accurate estimates of the size of their lawn. Homeowners tended to be 65% too large in their estimates, though a 95% confidence interval suggests that the actual amount off could be between 33% too large and 97% too large.

In light of this challenge to the data set, the best I can do is offer a range of possible application rates. In order to do this, I adjusted all reported lawn sizes down by 33% (lower bound), 67% (middle), and 97% (upper bound) before calculating application rates. Ultimately, I found that the mean application rate is between 1.9 and 2.8 pounds of nitrogen per 1,000 square feet per year, with the middle being at 2.4 (Table 1.1). While this estimate is not very precise, it does appear to be accurate as it is

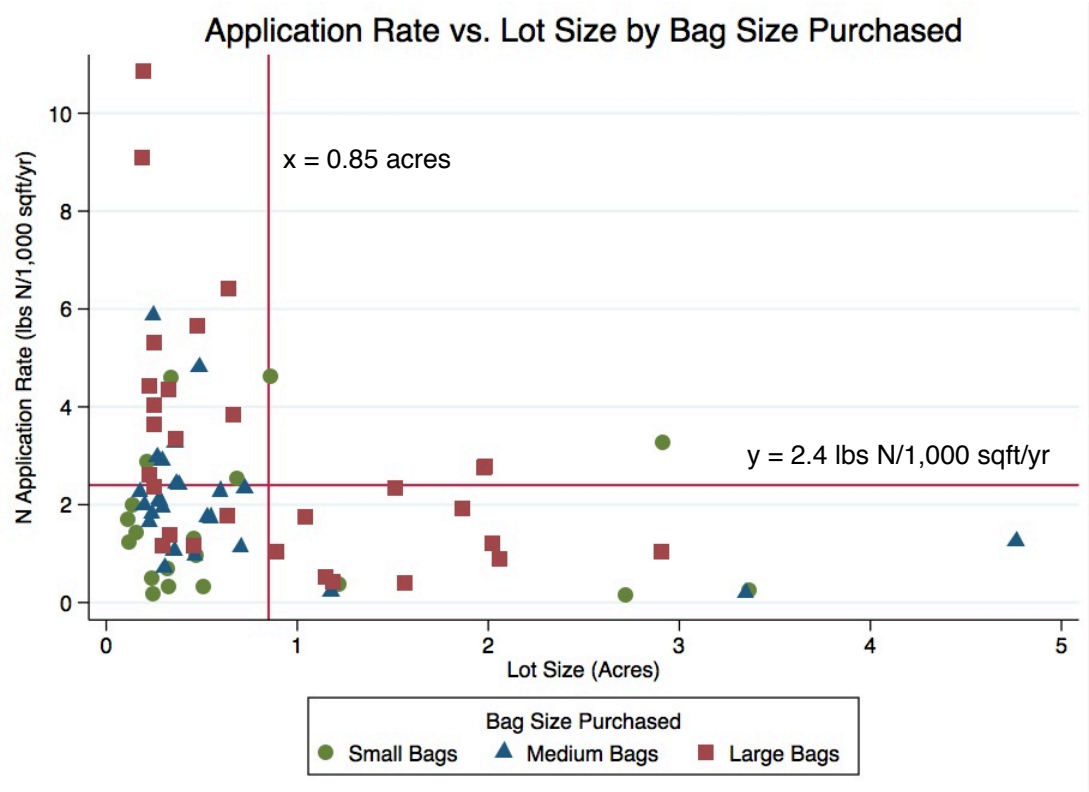
Table 1.1: Mean estimated application rates (lbs/1,000 sqft/yr) for Nitrogen, Phosphorus, and Potassium at three different levels of error (Median in parenthesis).

Nutrient	Middle	Lower Bound	Upper Bound	n
Nitrogen	2.4 (1.9)	1.9 (1.6)	2.8 (2.3)	74
Phosphorus	0.4 (0.1)	0.3 (0.1)	0.5 (0.1)	74
Potassium	0.7 (0.5)	0.6 (0.4)	0.8 (0.6)	74

in the same ballpark as estimates found in other studies.[4,5] The medians were consistently lower than the means, ranging between 1.6 to 2.3 lbs/1,000 sqft/yr, indicating the means are being dragged upwards by exceptionally high application rates. All together, these estimates suggests that roughly one-quarter to one-half of DIY homeowners in the county are at risk for over-applying fertilizer to their lawns. The estimates further suggest that a few high over-appliers are responsible for the bulk of the over-applied fertilizer.

Regardless of the validity of the estimate, there is one very interesting and important relationship between estimated application rates, bag size and lot size. Almost all of the homeowners with high estimated application rates live on lots that are less

Figure 1.4: Scatter plot of application rates versus lot size by bag size.



[4] Osmond, DL (2004).

[5] Law, NL. et al (2004).

than 0.85 acres in size *and* reported purchasing either medium or large bags (Figure 1.4). In other words, the group that appears to be most prone to high fertilizer application rates is homeowners with small- less than 1 acre- lot sizes. Possibly the simplest way to encourage this group to fertilize at a lower- and probably more appropriate- rate is to encourage them to buy small bags of fertilizer.

One last observation can be made from the fertilizer rate analysis that is independent of how accurate the rates are. Nitrogen, phosphorus and potassium should generally be applied at a ratio of 4:1:2. The ratio of NPK for estimated application rates is closer to 6:1:2, though in half or more of lawns the ratio is closer to 20:1:5 (based on median values). This deviation is due to the fact that many commercial fertilizers on the shelf today have very little to no phosphorus in them. Not coincidentally, the lawns that did have high phosphorus application rates were also the lawns that were fertilized with 3-in-1 fertilizers that are meant for garden use. The main takeaway here is that high nitrogen application rates do not necessarily mean high phosphorus application rates and, conversely, reduction in nitrogen application rates do not equate to reductions in phosphorus application rates for DIY homeowners.

Conclusion

The results from the survey are fairly clear in that there is significant room for improvement for residential fertilizer application practices inside Durham County. Both over-application of fertilizer and misapplication of fertilizer appear to be common issues inside Durham County, with at least 1 in 2 DIY homeowners being at risk for inappropriate fertilizer application in one way or another.

Fortunately, the issue primarily appears to be one of lack of knowledge rather than lack of motivation. This follows from several findings in the study. For example, most homeowners don't know how to calculate fertilizer application rates, which is easy enough to do once a person knows what numbers to use and what to do with them. The vast majority of respondents also did not know what "best management practice" stands for, even though most people reported regularly following many common BMPs. Finally, the fact that 30% of DIY homeowners reported frequently or always fertilizing before major rain events suggests that some people are simply mis-informed about some aspects of lawn maintenance. A strong education campaign should do much to remedy these problems.

One final question remains in my mind. How significant is one-quarter of one-half of Durham County homeowners? For example, if only half of the homeowners in the county fertilize their lawn and only one-quarter of those people don't bother to sweep impervious surfaces afterwards, how big of a problem is that, actually? It is difficult to say exactly, but some simple back-of-the-envelop numbers may give some perspective on the issue.

The maps I generated above were based on 56,000 addresses that matched up between the Tax Parcel data set and the Voter Registration data set. All of the addresses are registered as single-occupancy, stand-alone units- no townhomes, duplexes or apartments. Another 10-15,000 such addresses remained unmatched between the two datasets, so 56,000 offers a reasonable, conservative number to work with. 50% of homeowners fertilize means that roughly 28,000 households in the county have lawns that are fertilized in a given year. We know from the BMP responses that roughly 25% of homeowners rarely or never sweep up, giving us 7,000 households in the county that do not follow that BMP. That is roughly 7,000 households that are at high risk of simply not sweeping up after they fertilize.

While this math is incredibly imprecise and the number “7,000” is largely meaningless, it does help us to see one thing. The order of magnitude of the problem in the county is in the thousands of households. In other words, while not ubiquitous, the problems posed by residential fertilizer application are certainly size-able ones.

TECHNICAL REPORT

Survey Methodology

1,000 single-occupancy households were surveyed throughout March, April and early May of 2013. Houses were randomly selected through a double-randomization process. First, 27 quarter square mile areas were randomly selected from around the county along with 13 other areas selected based on specific County interests. Then 25 households were randomly selected from each of the 40 target areas. Participants received up to four contacts. The first two contacts, one week apart, invited the participants to take the survey online. The third contact, in week 4, contained a full paper version of the survey. The final contact, in week 7, contained a partial paper version of the survey.

The following sections cover the survey instrument, pre-testing of the survey, sampling methodology, and possible sources of error in greater detail.

Survey Instrument

Survey Questions. The survey followed a logical flow, placing critical and simple questions about lawn fertilization and best management practices early on while leaving more involved questions about grass type, fertilizer purchases, and lawn size for later in the survey. Test questions occurred last in the fertilizer portion of the survey so as not to deter participants from continuing. The septic system question set (not discussed in this report) followed the fertilizer section. Finally, the geography question set and demographic question set concluded the survey. For the full and partial paper survey, see Appendix A. The online version can be viewed (and taken) at sites.duke.edu/survey. The inlay below contains a more detailed list of the topics covered.

Question topics included the following(in order):

- Presence of a lawn and the responsibility for maintaining it
- Whether the lawn was fertilized and who by
- Importance of an attractive lawn (Likert)
- Live under a Homeowners Association with rules on lawn care
- BMP questions (Likert)
- Fertilizer application tool (e.g. spreaders)
- Lawn watering behavior and in-ground sprinkler system
- Attentiveness to fertilizer bag instructions
- Attentiveness to contractor's behaviors
- Grass type and months fertilizer applied in
- Fertilizer bag size, number and kind purchased and quantity of bag applied
- Contractor costs and services purchased
- Lawn size questions
- Fertilizer test questions
- Septic system questions
- Geography questions, including slopes on property and proximity to river or lake
- Demographic questions

Most of the questions in the survey were constructed as multiple choice. The BMP questions were primarily Likert-type questions with responses ranging from "Never" to "All the Time." Only a few questions required write-ins, such as lot size or amount spent on a contractor.

All questions related to fertilizing the lawn, fertilizer purchases and contractors were framed in terms of last year. I felt that the best way to collect information on people's current behaviors would be to constrain them to the most recent complete year. Focusing only on a specific time-period- a recent one at that- also helps to focus the participant and

aids in their recall ability. All other questions, such as BMP questions, were framed in terms of participant's general behavior.

One of the most important aspects of the survey involved estimating how much fertilizer people were applying to their lawns, or their fertilizer application rates. In order to estimate application rates, four key pieces of information were required. First, I needed to know how many bags of fertilizer they applied (Question 27), how large the bags were (Question 26), and what kind of fertilizer was purchased (Question 29). I also asked about how much of a bag was applied per application (Question 28); but this information was not required to estimate application rates. Finally, because application rates are in pounds per 1,000 square feet per year, I needed to know the area fertilized (Questions 33 and 34).

The first two pieces of information were easy to solicit. The respondent simply needed to give a number or indicate if the bags were small, medium or large. The third piece of information, fertilizer type, was more difficult as respondents could not be expected to recall, without aide, the types of fertilizer they bought the previous year. Dr. Osmond suggested providing a list of brands and types to help homeowners make their selection. Following on that advice, I visited Lowes, Home Depot and Walmart and recorded the brand, type, size, and NPK values of every fertilizer they had on their shelves. I then provided a list of these brands and types, with their NPK values in parenthesis, for homeowners to select from. I also provided a short list of "generic" fertilizers that represented the average NPK values for a given type (e.g. Generic Lawn Fertilizer or Generic Weed and Feed).

The final piece of information was the hardest to collect. I could not reasonably expect any homeowner to know the exact square footage of their lawn. I could ask them to estimate the square footage; however, that would involve more thought and math than most homeowners would likely have been willing to commit. Ultimately, a reasonable solution was proposed at a focus group. I asked homeowners what the size of their lot is and then asked them to estimate how much of the lot is mowed. From that I could easily compute square footage estimates for homeowners' lawns.

In order to double check the estimates received from the survey, I also offered homeowners the option to have me come and visit their home to measure their lawn and take a soil sample. The lawn measurements will allow me to assess how far off the estimates for lawn size are. The soil samples will help to inform the validity of the application rates and behaviors I recorded from the survey.

Survey Versions. The online version of the survey was drafted in and administered via Qualtrics (Qualtrics.com). The online version was then exported and adapted for paper in Apple's Pages software. Only minor changes, such as moving some comments sections, were made between the two version of the survey. The full paper version of the survey comprised 6 pages, front and back (12 total). The abridged version was half that length at 3 pages, front and back (6 total) (Appendix A).

The abridged version of the survey was designed with several goals in mind. First and foremost was the desire to minimize surveying costs while maximizing response rate. The final mailing of a survey always receives the lowest response rate; therefore, I did not see the benefit to the County of paying the full cost of printing and mailing the full survey a second time. Further, the final mailing is usually responded to by participants that are caught on the edge between filling out the survey being worth their time and filling it out not being worth their time. Thus, I felt that significantly reducing the length of the survey would be a viable means of increasing the number of participants who would feel responding was worth their time.

The second key goal of the abridged version of the survey was to bolster response rates to key areas of the original survey. After receiving and reviewing most of the online responses, I could see clear areas and questions that needed more information and that would be critical to the success of the survey. Key areas of interest were the BMP questions, questions about grass type, questions about fertilizer bag purchases, questions about lawn size, and demographic questions. Questions were dropped if they did not seem as critical to the survey and if I felt that I already had enough information on them from the previous contacts.

Pre-testing

The survey instrument underwent peer-review, focus groups and some pre-testing. Peer-review included regular reviews by officials with Durham County Government as well as feedback from several professors at Duke University's Nicholas School of the Environment and Sanford School of Public Policy. Pre-testing primarily involved having family, friends and County Officials take the online version of the survey to check it for programming errors.

Two focus groups were run on January 17th and January 22nd of 2013. The groups were comprised of Durham County citizens and attended by myself and one County staff member. The first focus group had 8 participants and was held at the Woodcroft Community Center. The group was primarily made up of members of the South Durham Green Neighbors.

Some participants lived in townhomes and found it difficult to contribute to the survey discussion. Otherwise, feedback was very helpful in adjusting the wording of questions and response options to be more specific, clear and inclusive. For example, "Not Applicable" was added as a response option to many of the first 17 questions. Additionally, questions about grass type were simplified by directly asking if the grass is brown or green in the winter-time rather than bombarding the reader with a list of grass types.

The biggest change made to the survey due to the focus groups was a decision to simplify the questions about lawn size. One participant suggested that the simplest and most fool-proof method would be to ask for the size of the lot and how much of the lot is actually mowed. Thus should give a rough indication of the actual area of the lawn. The original method asked respondents to estimate the actual size of their front, back

and side lawns. This method would have been tedious, difficult and inaccurate at best. As a group, we reasoned that the new method would get a better response rate due to its brevity and simplicity. The new method also helped to keep survey fatigue down, as compared to the original method.

The second focus group was held at Durham South Regional Library but only had two participants. The meeting was still productive as it allowed for the changes suggested in the previous group to undergo further review. No new changes were made as a result of the second focus group.

Sampling Methodology

The survey was targeted at single-occupancy homes, excluding townhomes, duplexes and apartments. Duplexes and apartments are almost always rented and rarely come with lawns that the renter is responsible for maintaining. Townhomes may be owned more frequently than rented, but also typically do not come with lawns that the resident is responsible for. Since the survey is centered on homeowners' lawn maintenance behaviors, it was logical to avoid multi-family structures.

Sample Area. Initially, the survey area included all lands within Durham County boundaries. However, with such a large area to cover and only 1,000 surveys available to distribute, County staff and I agreed that certain lower-density areas in the county could be avoided (Appendix B, Map A). Specifically, areas in the northern half of the county and in the far east of the county were excluded from the survey area. Much of the land in those areas is in agriculture, for which County staff already has detailed records of fertilizer applications.

Table 2.1: Census tracts omitted from sample area.

Tract #	Explanation
3.01	High non-target housing and rental rate
4.02	High non-target housing and rental rate
13.01	High non-target housing and rental rate
15.01	Duke West Campus
15.02	Duke students- mean age 26.2; 88% rental rate
15.03	Duke East Campus
20.16	Apartments
9801	RTP

After establishing the sample area, I then needed to determine what parts of the county within that area could be deemed non-target areas. A non-target area primarily is defined as an area with a high rental rate and/or a low single-occupancy home density. To determine non-target areas, I used a combination of 2010 US Census data at the census tract-level, Google Maps and Apple Pages.

First, I used the Census data to identify tracts that should be entirely omitted from the study (Table 2.1). Blocked out tracts included Duke University's East and West campus and other areas with high rental rates. I then proceeded to examine each tract via Google Maps in satellite mode. I identified areas in Google Maps that had

apartments, townhomes, duplexes, or substantial commercial development. These areas were then blocked off, using streets as a guide. (Appendix B Maps 1 & 2)

To perform the actual mechanics of blocking out non-target areas, I imported the high resolution 2010 Durham County Census tract map into Apple's Pages word processing software. The map allowed me to see all streets, permanent waterways, and census tract boundaries in detail. Pages has a simple tracing tool that allowed me to create and fill in the requisite shapes with accuracy.

Sampling Grid. In order to perform the double randomization sampling technique, I needed a grid or other means of sampling evenly sized areas in the county. The 2,500 ft Atlas Locator Grid provided the best answer. The grid squares are 2,500 feet on a side (or 0.224 square miles in area) and are typically used for mapping purposes. Each grid is associated with a unique number in the County's GIS database, allowing me to match homeowners to specific grid squares for sampling purposes. I exported a map of the county with the grid overlay from Durham County GoMaps, then performed a series of my own overlays in Pages to match that map with the Census tract map and edits from earlier. Finally, I overlaid spreadsheet tables sized to match the 2,500 ft Atlas Locator Grid so that I would have an editable grid for sampling.

The GoMaps map was then deleted, leaving the Census map as the base map for the county, a series of objects blocking out the non-target areas in the county, and a series of tables precisely matching the Locator Grid. Areas in the grid that corresponded with non-target areas *outside* the sampling area were filled in black. Areas that corresponded with non-target areas *inside* the sample area were colored in red. An area was colored in if 40% or more of that area was outside the sampling area or comprised of non-target area inside the sampling area. The grid was then numbered accordingly. (Appendix B, Map 3)

Areas Sampled. With the sampling map in place, 40 grid locations (tiles) were selected. Twenty seven tiles were selected at random while 8 tiles were sampled specifically for the fertilizer portion of the survey based on County staff interest. A further 5 tiles were sampled specifically to ensure that septic system users were included in the sample frame. Ultimately, it was necessary to go outside the sample area in order to fill the septic system needs. (Appendix B, Map 4)

Towards the end of sampling, I realized the selections were mostly from the outlying areas around Durham, with few areas from the urban city center. I thereby created three zones on the map on a somewhat ad hoc basis. I confined the last 3 random samples to the area demarcating the urban city center. Finally, if a tile was randomly selected to be adjacent to another one already in the sample, it was replaced and resampled to deter clustering of sampling areas.

Some tiles appeared to have a low-density of houses in them. To ensure a full sample of 25 homes could be taken from each sample area, one additional tile adjacent to the base tile was added to the sample area. To do this randomly, an octahedron with

sides labeled 1 through 8 was rolled. Starting from the tile directly above the origin tile, tiles were counted off clockwise until the number shown on the octahedron was reached. If it was useable, that tile was then added to the sample area for the base tile.

Households Sampled. Households were sampled from Durham County's Voter Registration (VR) dataset. The VR data included all registered voters inside the county that could be mapped to addresses in the County's GIS database. I imported the dataset into Stata for cleaning and sampling. First, I purged the data of all addresses associated with Duke University. Second, I purged the data of all obvious apartment and duplex residents by matching the length of two separate addresses provided in the VR dataset. One address variable contained the street address and apartment or duplex number while the other address variable simply contained the street address.

Finally, I used Google Maps to methodically go tile-by-tile through my sample and pinpoint all remaining possible duplexes, townhomes, and apartments that might fall inside my sample area. In some cases, whole streets were removed form the dataset due to most of the houses on the street being townhomes or duplexes. My search also yielded the removal of several hundred entries associated with TROSA and 40 entries associated with the North Carolina School of Science and Mathematics. Finally, a few addresses were dropped as they had 9 or more residents registered to them in the VR dataset. These addresses were most likely student rentals.

I could now begin taking my 1,000 household sample. Twenty five households were sampled from each of the 40 sample areas. Some sample areas had two or more tiles associated with them, as discussed above. In any case, I used the unique "mapsheet" number associated with each 2,500 ft Atlas Locator Grid tile to ensure that households were sampled from the correct areas. The final sample included 2,097 registered voters inside Durham County, representing 1,000 individual households.

Follow-up Home Visits

I conducted follow-up visits with 31 willing participants from the survey. I selected participants based on whether or not they had expressed interest on the survey and had responded to a subsequent scheduling email. To save time and gas, I focussed on visiting two or three homes in the same sampling area for a given day. A total of 15 sampling areas were represented in the follow up visits.

I measured off lawns as precisely as possible with a Lumkin measuring wheel. To get a "precise" measurement, I broke the lawns up into smaller pieces, such as trapezoids, rectangles, triangles, circles, and ovals (see Appendix C for recording sheet). Islands were typically measured and subtracted out. While this process was not perfectly precise (due to the many dips and turns landscaping often has in it), it removed the human error in estimating sizes.

I also took soil samples from 28 of the 31 lawns measured. Soil sampling was done per the directions of the North Carolina State University (NCSU) soil lab. Generally, 6 to 10 4 inch long, 4 inch deep, and 1 inch wide holes were dug at random

around the lawn. The soil was taken from the holes and thoroughly mixed in a bucket until all samples from a lawn were essentially one. Soil samples were then boxed and sent to NCSU for processing via the Durham County Soil and Water Conservation District's office.

Additional information was also gathered during the home visit. I took notes on the level of maintenance of the lawn and the type of grass. Finally, homeowners that had reported not fertilizing their lawn last year were asked the following three questions.

1. When did you last fertilize your lawn?
2. Why did you choose to not fertilize last year/in general?
3. Will you fertilize the lawn in the future? If so, when?

Sources of Error

Several sources of error are inherent in the survey method outlined above. Recall error, self-reporting bias, geographic distribution error, and estimation error are the primary sources I will consider here.

Recall Error. The survey is heavily dependent upon respondent's ability to recall their past behaviors accurately. The one-year time frame helps to reduce this source of error by focusing the participant on a recent and narrow timeframe. However, buying and applying fertilizer is not a significant life event. It is highly unlikely that many people can recall these behaviors from the previous year with 100% accuracy.

What is more likely is that people are reporting what they did last year based in part on what they plan to do this year. How this may affect the accuracy of their reporting is hard to say. However, any reporting based on future plans is problematic. I am interested in hard actions rather than soft intentions. Plans and intentions, like life, are often highly fluid. Alternatively, respondents may have also defaulted to what they do in a "typical" year to aid in responding to questions about last year's behaviors.

Self-reporting Bias. Self-reporting bias is another potential problem, particularly where the BMP questions are concerned. Two possible issues may arise here. One is that respondents answer the questions based on their intentions- i.e. "I intend to sweep the driveway all the time; therefore I do"- when, in fact, the respondent does not commit the behavior as frequently or infrequently as they would like to think. Alternatively, the respondent may know what the correct behavior is and over exaggerate how often they do it. For example, the respondent might say they always sweep when they know they never do. In both cases, the bias will lead the results towards a more favorable outcome.

There are two possible ways I might have minimized this source of bias. One is that I could have asked for participants to report on neighbor's behaviors. This method would have been severely flawed in its own right. For one, not everyone pays that much attention to their neighbors. For another, some people would have responded not based on actual fact, but on their general opinion of their neighbor. Alternatively, I might have

asked respondents to answer the BMP questions relative to the last time they fertilized. This approach, however, would have taken me right back into the previous issue of recall error while still leaving the questions vulnerable to self-reporting bias.

Estimation Error. There is also error associated with the estimations required in the lawn area questions. Not every homeowner knows the exact size of the lot they live on, in which case they first have to estimate the total area of their property. More difficult and error prone, however, is the second estimation of how much of their lot is mowed. I provided respondents with a fixed set of approximations at 10%, 25%, 33%, 50%, 66%, 75%, and 90% to facilitate this estimation. However, as the sample area is in the Piedmont, most lots in the county are hilly and oddly shaped, not flat. Add to the terrain the presence of odd shapes like a house and other landscaping, and the odds of the respondent picking the correct approximation decrease even further.

I will attempt to control for the estimation error by comparing estimations with the relatively precise measurements of homeowners' lawns taken in the follow-up home visits. Final results will be adjusted according to these comparisons by using the mean error and the upper and lower bounds from a 95% confidence interval around the mean error between estimates and measurements.

Geographical Distribution Error. Finally, the geographic distribution of sample areas throughout the county may not be suited to capturing a representative sample of the county. Some areas, such as southern Durham City in the Woodcroft area, are almost wholly unrepresented by the sample areas. Further, the largest portion of survey areas come from the more rural parts of the county at the edges of or outside Durham city limits. Yet the highest density of homes is inside the city limits- particularly near downtown Durham.

Analytical Methodology

Statistical Analysis

Stata/IC 11.2 was used for all statistical analysis and number crunching. Pearson's Chi-squared tests were used for two-way tabulations. Probability Unit Regression Analysis (Probit) was used to examine the relationship between different predictors and the likelihood of fertilizing the lawn or hiring a contractor. Probit was also used to produce the models upon which the geographic maps of Durham County are based.

Imported values from external sources were used in place of certain variables in the survey dataset due to limitations of the original data. Table 2.2 lists what variables were replaced with what, the parent dataset of the new variable, and a brief explanation of why the variable was replaced.

Table 2.2: List of variables replaced by external data, including source and reason.

Old Variable	New Variable	Parent Dataset	Explanation
Reported Age	Mean Age of Registered Voters	Voter Registration	Accounts for mixing of generations within a household
Reported Income Bracket	Total Property Value	Tax Parcel	More complete, more continuous, wider range, realistic upper bound
Reported Lot Size	Parcel Acreage	Tax Parcel	More complete and more accurate

Additional Datasets

The County Tax Parcel dataset is updated daily except during brief periods when it is frozen by the tax office. Thus, the data was highly current at the time of my use. The primary systematic error that occurs in the dataset concerns residents such as condominium owners. The condominium owner may own their unit, but not show up in the dataset because they do not own the land their unit is above. This issue has no effect on my use of the dataset since I was expressly not interested in multi-unit dwellings such as condominiums.

The Voter Registration dataset is updated periodically upon request. It was last updated specifically for this project in January of 2013. The dataset has some systematic errors associated with it. The most concerning issue is that, while individuals may be added to the dataset, they are never removed. This fact explains why some surveys were delivered to residences where the former owner was either recently deceased or, as in one case, had been deceased for two years.

The largest concern this issue raises is whether or not the mean age generated for a household is representative of the current household, the past household, or the current *and* the past household. Of the 400 respondents to the survey, only the handful that reported moving into their home less than 6 months prior to taking the survey are likely to be misrepresented by the previous owners in the VR dataset. It is possible that some households in my survey sample and in the larger sample used for my models are a mix of both past and present residents. However, this would be difficult to tell unless it were clearly a case of two families of 5 sharing the same unit. This scenario would most likely drag the mean age down as an older owner is replaced by a younger owner. I have no means to account for this error in the results, nor do I have reason to expect it is a significant source of error.

Finally, some registered voters could not be geocoded for one of two reasons. The largest group is voters whose mailing addresses are different from their street addresses, as is the case in some low-income housing developments. Similar to the condominium issue, this source of error is of no consequence to this survey. The second reason that a person might not be geocoded is because they failed to list a cardinal direction for the street name. This may or may not result in the exclusion of a household from the VR data set and might also bias mean ages for households.

However, the extent of the issue is difficult to gauge, though likely small relative to the size of the dataset.

The final GIS maps produced for this report were the result of my efforts to merge on address the Tax Parcel dataset and the Voter Registration dataset. Before the merge, I attempted to clean both datasets by removing extraneous spaces, matching letter cases, and homogenizing street naming conventions. In some cases, the correct cardinal direction was identified and input. Not all addresses were corrected, however, due to the time-intensive nature of the process relative to the minimal returns I was gaining from it. Table 2.3 lists the land-use codes that were included in the final merged data set and the number of addresses for each code. The final dataset comprised 56,658 matches. Over 11,000 addresses remained unmatched in each of the parent datasets (22,917 total). Of the 56,658 addresses that did match, 53,671 (95%) are single-residences (land use code 111).

Table 2.3: Land use codes and number of residences associated with each.

Land Use Code	Description	# Matched
100	Residential - Less than 10 Acres	1
105	Residential - Includes leasehold	1
110	Residential - Year-round residence	2
111	Residential - One family residence	53,671
112	Residential - Two family residence	0
113	Residential - Three family residence	0
11102	Residential - One family RENTAL	574
11142	Residential - One family S42	73
120	Residential - Condominium and Townhouse	0
140	Residential - Rural with acreage	1,628
150	Residential - Luxury estates	32
190	Residential - Historic	26
200	Agriculture - 10 acres or greater	3
210	Agriculture - Year-round residence	3
211	Agriculture - One family residence	171
		56,185

Results & Analysis

Follows is a summary and statistical analysis of important findings from the survey.

Response Rates

The final response total was 411 out of 1,000, or 41% response rate. Thirty nine surveys came back as non-deliverable, for a 4% non-delivery rate. Only one survey was mauled by a dog, for a low 0.1% dogged rate (the data was recoverable).

At least two of the anonymous responses are duplicates as two respondents reported filling out the survey for all 3 contacts. However, these respondents only included their ID on the last survey, making it impossible for me to determine which of the other anonymous responses were theirs. One person reported living in a townhome

and so their response was removed from the dataset. I spot checked respondents that reported not having "a lawn they are responsible for maintaining." As a result, 5 more responses were removed as they also lived in townhomes or apartments.

Responses were divided evenly between online and paper surveys. 202 out of 204 online responses were ultimately useable, while 151 out of 152 full paper surveys and 49 out of 55 abridged surveys were kept. In final, the dataset is comprised of 403 responses, 202 of which were filled out online and 200 of which were filled out on paper. The difference between paper and online is important to note as the mean age, mean level of education, and mean years at address are all significantly different ($p<0.05$) between paper respondents and online respondents. Paper respondents are generally older, less educated and have lived in their home longer than online respondents.

Item non-response, where a respondent sees a question and then chooses not to provide an answer to it, was generally not a problem. The question that suffered the most from item non-response was the question about lot size. 92 respondents, or nearly one-quarter of respondents, left the question blank. Having an estimated lot size is critical to estimating the lawn size and then, when applicable, estimating the fertilizer application rate. For this reason, the estimated lot size given in the County's Tax Parcel data set will be used instead of the acreage given by homeowners as the County Tax Parcel data is more complete (85 missing values).

The other variable troubled by lack of data was income. One-third of respondents either refused to give an income estimate (n=113 or 28%) or left the question blank (n=20 or 5%). This result is not surprising. Ultimately, income will be replaced by property value, as given in the County's Tax Parcel data set.

Demographics

Participants in the survey were generally older, with a mean age of 56 years (Table 2.4). Households had an average occupancy size of 2.4 persons, with only 20% of households reporting having a single occupant. Respondents reported living at their addresses an average of 15 years, with half of respondents reporting living there more than 12 years and half reporting living there 12 years or fewer. Nearly all respondents reported owning their own home (92%).

Table 2.4: Summary of key demographic variables.

Variable	Mean	Median	Min	Max	n
Age	56.4	58	24	95	375
Years at Address	15.0	12	0.125	69	392
Occupants	2.4	2	1	7	390
Income	$101,000	-	-	-	269
Property Value	$242,000	$200,000	$31,500	$849,000	317
Lot Size (Acres)	0.79	0.45	0.11	9.16	317

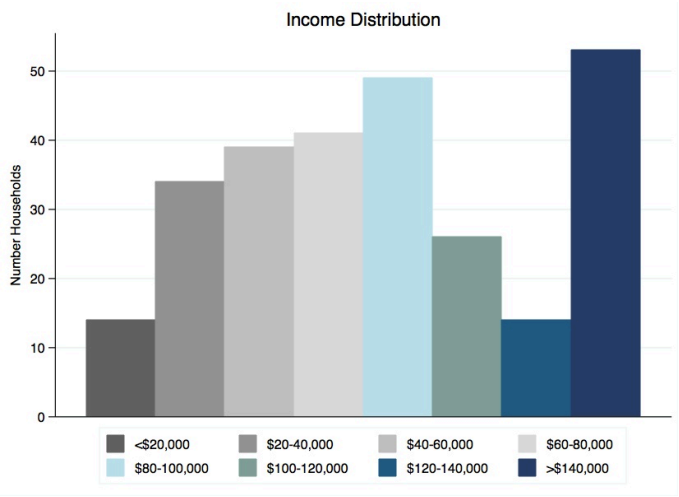
Property values covered a very wide range, with the minimum value being $31,500 and the maximum being $849,000 (Table 2.4). The median property value for respondents was $200,000. Lot sizes also covered a wide range. Lot sizes ranged from

0.1 acres to 9 acres in size. The mean lot size for respondents is 0.8 acres while the median lot size is 0.5 acres. All values reported are from County Tax Parcel data. Reported lot sizes proved unreliable as the mean and median were both significantly higher while some lots that were reported to be very small (0.1 acres or less) turned out to be significantly larger (0.3 acres or more).

Table 2.5: Summary of education responses by highest level completed.

Education	n	%
Some High School	5	1.3
High School/GED	15	4.0
Some College/Technical	59	15.6
College/Technical	129	34.1
Graduate	170	45.0

Figure 2.1: Distribution of annual household incomes.



Not surprisingly, Durham homeowners tended to be highly educated (Table 2.5) and middle income (Figure 2.1). Nearly half of all respondents reported having a graduate level degree, while only 5 respondents reported having not completed high school. Of those who responded to the income question, respondents reporting earning over $140,000 per year comprised the largest group with the $80-100,000 per year range coming in a close second. Estimated mean income for sample respondents is $101,000 per year.

Who Applied Fertilizer

Only 11 of the 402 participants (2.7%) responded that they did not have a lawn that they were responsible for maintaining. Of that eleven, three reported to be renters and may not be responsible for the maintenance of their lawn. The remaining 8 all appear to not have lawns, based on Google Maps satellite imagery.

Of those participants that did report having lawns that they were responsible for, slightly more than half reported fertilizing their lawn last year (Table 2.6). Chi-Squared tests revealed that education level, income bracket, living in an HOA, and having an in-ground sprinkler system are all positively correlated with a household choosing to fertilize their lawn last year ($p<0.01$). Only 3 out of 19 households reporting high school or less as their highest level of education fertilized their lawn while half or more of respondents with some college or more did fertilize. Further, over 80% of respondents who live in HOAs fertilized and 90% of respondents that reported having in-ground sprinkler systems fertilized.

Table 2.6: Number of respondents that reported applying fertilizer.

Fertilized?	n	%
Yes	206	52.7
Self	*111*	*53.9*
Contractor	*95*	*46.1*
No	185	47.3
Total	391	100.0

Table 2.7: Results from probit regressions to predict whether homeowner fertilized lawn last year.

Variable	1	2	3
[Constant]	-1.16***	-1.14***	-1.069***
Property Value	4.25E-06***	2.04E-06**	2.98E-06***
Mean Age	0.0009	0.009	0.006
Years at Address	-0.006	0.000	-
Lot Size	-0.19**	-0.10	-0.12
HOA	-	0.67***	0.78***
Sprinkler	-	1.06***	-
n	305	260	306
df	4	6	4

**Significant at p<0.10; **Significant at p<0.05; ***Significant at p<0.01*

I ran Probit regression analyses to further explore the relationship between decisions to fertilize and possible predictors (Table 2.7). Initially I included education level, property value, mean age, years at the address and lot size (as given in tax parcel records) in the regression (not shown). However, education was highly insignificant in the analysis, so I dropped it from the regressions (p=0.98). All initial regressions indicated that property value and lot size were highly significant to whether or not a household chose to fertilize (p<0.01) (Column 1).

I then added two more predictors to the regression analysis- living in an HOA and having an in-ground sprinkler system (Column 2). This dramatically altered the results of the regression. The coefficient on property value more than halved, though it still remained significant (p<0.05). Lot size, however, not only decreased in size but also became non-significant in the regression (p=0.22). Living in an HOA or having an in-ground sprinkler system, however, were both highly significant to whether or not a household applied fertilizer (p<0.01).

To round out my regression analysis, I added one last predictor (not shown). I generated an interaction term to represent households that *both* live in an HOA *and* have an in-ground sprinkler system. The majority of the households that reported having in-ground sprinkler systems also reported living in HOAs (n=38). Of those that reported both, only 2 did not fertilize last year. Unfortunately, the inclusion of the interaction term blew out the regression. This is likely due to there being a strong correlation between property value and having an in-ground sprinkler system.

As a side note, using robust standard errors in the regressions was actually *shrinking* my error terms; I therefore chose to report non-robust standard errors.

DIY vs. Hire Contractor

Of the roughly half of respondents that reported fertilizing their lawn last year, 54% reported doing it themselves while 46% reported hiring a contractor (Table 2.6). This

Probit Output and Z-Scores Explained

The numbers in Tables 7 and 8 do not translate directly into probabilities or percent chances. Instead, they translate directly into a "Z-Score" that must then be used to find the probability of an outcome. Say you want to know the probability that a young person living in a recently purchased house valued at $75,000 will fertilize their lawn. Lets say their lot size is only 0.25 acres and they do not live in an HOA or have a sprinkler system. In order to do this, you need to use the numbers from Column 2 of Table 7 to make an equation (Eq. 1).

Eq. 1: (Property Value)*2.04E-06 + (Mean Age)*0.009 + (YaA)*0.000 + (HOA)*0.67 + (Spr)*1.06 - (Lot)*0.10 - 1.14 = **Z-Score**

The constant at the end represents a person that is 0 years old, with $0 property value, 0 years in a home, and who does not live in an HOA or have a sprinkler system. Next, plug in the appropriate values and compute (Eq. 2). If you wanted to assume the person lives in an HOA, you would plug in a 1 instead of a 0 for HOA. Likewise, if you are curious about someone that has a sprinkler system, you would plug in a 1 for sprinkler.

Eq. 2: (75000)*0.00000204 + (30)*0.009 + (1)*0.000 + (0)*0.67 + (0)*1.06 - (.25)*0.10 - 1.14 = **-0.74**

Now that you have a Z-score, you can convert it to a probability. You will need the chart provided in Appendix Z at the back of this document. On the left hand side of the chart, find -0.7. Then find 0.04 along the top of the chart. Where the column and row converge is a number- that is your probability. In this case, the Z-score of -0.74 equates to a 23% chance that the individual will fertilize. Put another way, if we had 100 individuals exactly like the one above, we would expect 23 of them to fertilize their lawn.

A few notes about Z-scores to keep in mind. First, note that a Z-score of 0.00 equates to exactly 50% probability. Second, a change in a Z-score of 0.1 matters a lot more when the Z-score is closer to 0.00 than when it is farther away. In other words, the Z-score is a lot more sensitive to small changes when it is near zero.

time, Chi-Squared tests found that only having an in-ground sprinkler system was significantly correlated with a household choosing to hire a contractor ($p<0.01$). Both income bracket ($n=130$) and education level ($n=192$) leaned towards higher levels hiring contractors more frequently; however, the relationship was not significant. This observation may mean that the relationships are not significant or it may simply be the result of smallish samples that do not have enough statistical power to detect significance.

I re-ran the regression in Column 1 of Table 2.7, only this time predicting the likelihood of a person hiring a contractor if they fertilized last year (Table 2.8, Column 1). All regressors were significant. Likelihood of hiring a contractor increases with property value, mean age and years at address but decreases with lot size.

I continued to build the model up by adding in the indicator variables for living in an HOA and having a sprinkler (Column 2). Again, the model changed dramatically as a result of the additions. The coefficient on property value decreased again but remained highly statistically significant ($p<0.01$). Age became less significant while years at

Table 2.8: Results from probit regressions to predict whether homeowner fertilized lawn themselves or hired a contractor.

Variable	1	2	3
[Constant]	-1.78***	-1.41***	-1.70***
Property Value	3.12E-06***	2.54E-06***	3.32E-06***
Mean Age	0.020**	0.015	0.025***
Years at Address	0.020*	0.024**	-
Lot Size	-1.02***	-1.07***	-0.98***
HOA	-	-0.27	-0.38
Sprinkler	-	0.89***	-
n	157	135	158
df	4	6	4

**Significant at p<0.10; **Significant at p<0.05; ***Significant at p<0.01*

address both increased in significance and coefficient. Interestingly, living in an HOA was not a statistically significant predictor, thought the coefficient is large enough to be meaningful. The regression model also suggests that living in an HOA decreases the likelihood of someone hiring a contractor. Owning an in-ground sprinkler system was significant and positive again.

Small lot size is highly correlated with living in an HOA, so it may be that the importance of living in an HOA is being masked by lot size. Dropping the lot size variable, however, yielded a much less significant value for HOA, a small sign change on the coefficient, and a much lower pseudo-R^2 value. Dropping HOA, however, resulted in a more significant regression, overall, and only a slight decrease in the pseudo-R^2 value of the model.

The correlation of homeowners with sprinkler systems and hiring contractors may be due to a common desire for attractive lawns. However, for homeowners that reported fertilizing their lawns, there was no statistically significant difference in how important having an attractive lawn is between homeowners that own an in-ground sprinkler system and those that do not own one (results not shown). In the end, the dataset is inconclusive on this point.

Fertilizer Application Rates

The following section goes through the process of estimating DIY fertilizer application rates. This report will not consider contractor fertilizer application rates.

Summary of Responses. 111 respondents reported fertilizing their lawn themselves. Of that number, 70% reported purchasing only 1 or 2 bags of fertilizer, while another 20% reported purchasing 3 or 4 bags. One-quarter of respondents reported buying small bags; one-third reported buying “medium” sized bags; and the remaining 40% reported buying large bags. Weed and feed and regular lawn fertilizer were the two most popular types of fertilizer purchased. Approximately 20% of respondents reported applying 10-10-10 to their lawn. Mean lot size for respondents that fertilized their lawns

themselves is 0.83 acres while the median is 0.42 acres. Mean estimated lawn size is 18,000 square feet while median lawn size is 10,600 square feet, based on reported lot sizes.

Estimation Error. As a reminder to the reader, lawn size was estimated through a two step process. First, respondents were asked to estimate the size of their lot, either as dimension in feet, area in square feet, or area in acres. Second, respondents were asked to estimate how much of their lot is mowed as a percentage. Possible responses were fixed at 10%, 25%, 33%, 50%, 66%, 75%, and 90%.

There are two points at which error can be introduced into lawn size estimates. The first and easiest to control for is error in reported lot size. Reported lot sizes are, on average, 20% larger than the actual lot size recorded in the tax parcel dataset. However, median lot size error is only 2%. This suggests that roughly the same number of people over-estimated their lot size as under-estimated it. However, the homeowners that over-estimated were off by a lot more than those that under-estimated. The simplest way to correct for this error is to only use tax parcel lot sizes from here on out. Unfortunately, this will still prove to be problematic, as will be discussed later on.

The second source of error comes in the estimation of mowed area. This source of error can best be measured by comparing the estimated lawn size with the measured lawn size for the 31 homes whose lawns were measured. All homes measured had at least either a reported lot size (n=29) or a tax parcel lot size (n=29); most had both (n=27). I estimated lawn size errors based on both the reported lot size as well as the tax parcel lot size for comparative purposes.

Summary statistics for the estimated errors can be seen in Table 2.9. As to be expected, error associated with reported lot sizes is larger than that associated with tax parcel lot sizes. There is an important observation in this. The fact that tax parcel error is lower means that homeowners were generally estimating the mowed area of their property based on the actual boundaries of the property rather then what they thought the size of the property to be. If respondents had been estimating mowed area based on the lot size they had given, then reported error would have been less than tax parcel error.

Table 2.9: Estimated errors using reported lot sizes versus lot sizes drawn from tax parcel information.

Group	Mean	Median	95% CI - Lower	95% CI - Upper	Sum Squared Err.	n
Reported	1.13	0.77	0.47	1.80	107.8	27
Tax Parcel	0.65	0.55	0.33	0.97	28.9	27

Finally, the sum of squared errors is significantly lower for tax parcel estimates, confirming that tax parcel errors are better suited for lawn size correction. Further, tax parcel errors were not correlated with responses to the mowed area question (r=-0.04), suggesting that the format of the question did not contribute strongly to the error in the lawn size estimates.

Before rates are calculated, lawn sizes will be adjusted according to the error amounts reported here. The three different rates will be based on the mean error, lower bound error and upper bound error from the 95% confidence interval.

Fertilizer Poundage. In addition to the lawn size, I also need a poundage for fertilizer applied during the year in order to calculate the application rate. While other studies have estimated nutrient amounts based on number of applications during the year, I will estimate nutrient amounts based on the number of bags reported purchased and the size of those bags. I will also use the number of different types of bags reported and the specific information for each type the respondent said they bought.

When I created the list of fertilizers for respondents to select from, I also collected information on the different bags' NPK rates, size in pounds and size in square foot coverage. For each brand-type combination that was reported as having been purchased, I created 5 new variables in the dataset- one each for nitrogen percentage, phosphorus percentage, and potassium percentage as well as for number of pounds in a small bag and number of pounds in a large bag. Using this information, I will be able to compute more accurate application rates for each respondent. More importantly, however, the final average will be properly weighted according to the types of fertilizer reported used by respondents in the survey.

In some cases, respondents reported buying 2 bags but listed 4 different types. In such situations, I averaged the types together in the process of generating the final application rate by dividing the reported number of bags they purchased by the total number of types they listed. This averaging effect took place for a total of 15 out of 92 respondents that answered both bag number and bag type questions.

Finally, approximately one-third of respondents indicated that they had purchased a "medium" size bag that covers 10,000 square feet of lawn. Such a bag size does not exist except for a select few specialty fertilizers (i.e. Milogranite Organic). One possibility is that a respondent was not aware of this fact at the time they answered the question. Another possibility is that they purchased a mix of large and small bags. In any case, I averaged the large and small bag sizes together for these respondents. This method is valid as a small bag covers 5,000 square feet and a large bag covers 15,000 square feet, such that the average of these two sizes is 10,000 square feet.

Application Rates. The final application rates were computed based on Equation 1,

Eq. 1 $N\text{-rate}_i = [\sum(Np_j * W_i) * Bn_i / Tn_i] / [Ls_i * Mw_i * 43{,}560 / (1+\varepsilon)]$

where sub-script "i" indicates an individual and sub-script "j" indicates a fertilizer type; N-rate is the final Nitrogen application rate in pounds per 1,000 square feet per year; Np is the percentage of Nitrogen in a bag; W is the weight of the bag in pounds; Bn is the number of bags reported purchased; Tn is the total number of types listed by the respondent; Ls is the tax parcel or reported lot size in acres; Mw is the estimated

percentage of the lot mowed; 43,560 is the conversion factor for acres to square feet; and 1+ε is the overestimation correction term.

Equation 1 was run six times. The first three times used the reported lot size and associated mean, lower bound and upper bound error amounts. The final three times used the tax parcel lot size and its associated error amounts.

Table 2.10 lists the results from the above calculations for nitrogen. The first two rows are rates for all respondents with reported lot size and all respondents with a tax parcel lot size, respectively. The third and fourth row are based only on respondents that have rates for both reported lot size and tax parcel lot size. Note that rates based on reported lot size drop slightly after 17 observations are eliminated due to not being shared with the tax parcel group (Rows 1 and 3). The tax parcel rates, however, largely remain the same (Rows 2 and 4). As it happens, the 17 observations that are excluded by the tax parcel group happen to have mostly above average application rates.

Table 2.10: Summary of application rates (in lbs N/1,000 sqft/yr) for nitrogen, based on reported and tax parcel lot sizes.

Group	Middle	Lower Bound	Upper Bound	n
1. Reported (All)	3.2	2.2	4.2	83
2. Tax Parcel (All)	2.4	1.9	2.8	74
3. Reported (Both)	3.1	2.1	4.1	66
4. Tax Parcel (Both)	2.4	1.9	2.9	66

Unfortunately there is no way to account for the missing rates, so simply the tax parcel method will have to be used for the final estimates. I considered including the 17 missing reported rates in with the 74 tax parcel rates; however, the extreme difference in error between the two groups would produce a seriously flawed result.

I repeated the process for phosphorus and potassium. Table 2.11 lists the three nutrients and the mean and median for each of the three levels of error.

Table 2.11: Mean estimated application rates (lbs/1,000 sqft/yr) for Nitrogen, Phosphorus, and Potassium at three different levels of error (Median in parenthesis).

Nutrient	Middle	Lower Bound	Upper Bound	n
Nitrogen	2.4 (1.9)	1.9 (1.6)	2.8 (2.3)	74
Phosphorus	0.4 (0.1)	0.3 (0.1)	0.5 (0.1)	74
Potassium	0.7 (0.5)	0.6 (0.4)	0.8 (0.6)	74

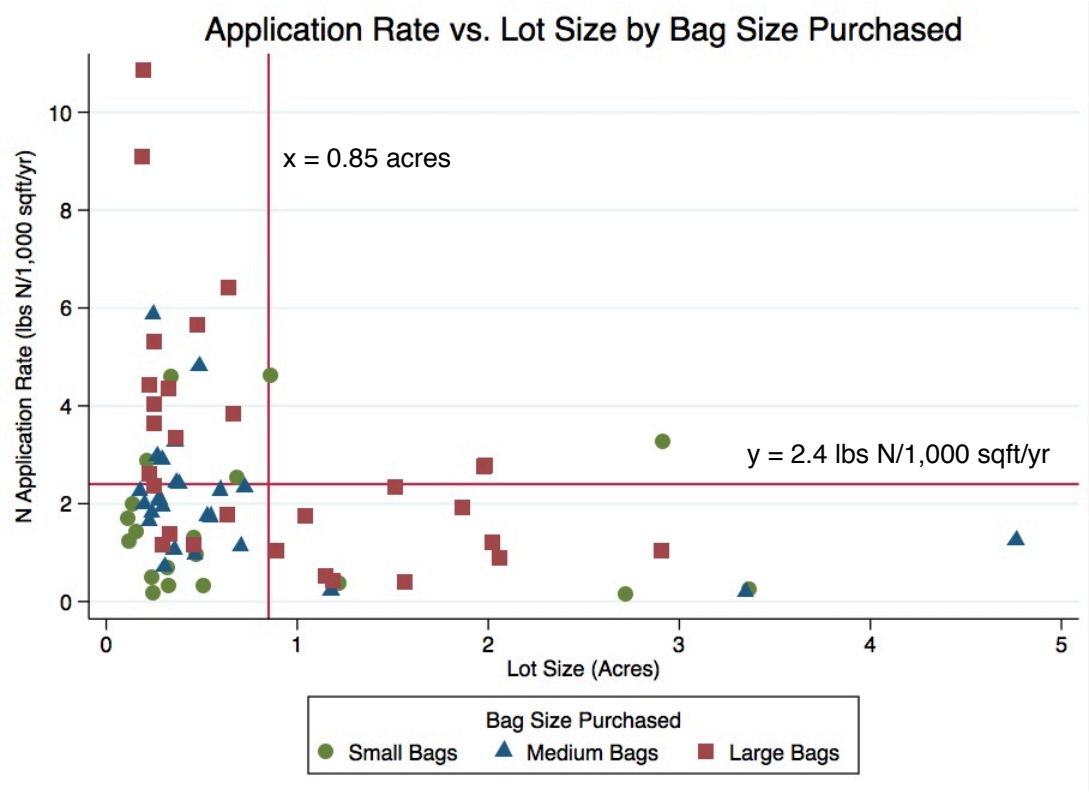
Two final items should be noted. First, this method assumes that once a bag is purchased, the entire bag is applied during the year. Second, this method assumes that all mowed area on a property is also fertilized area. Home visits have revealed both assumptions to not always be the case. Nevertheless, the former of these two assumptions inflates the final application rate for some households while the latter deflates the application rate for others.

Analysis of Rates. Mean application rates are significantly lower for homeowners that reported buying small bags of fertilizer versus those that reported purchasing medium or large bags ($p<0.05$). Likewise, homeowners that reported buying only 1 bag had significantly lower application rates than those that reported purchasing 2, 3 or 4 bags ($p<0.05$).

The biggest thing respondents that were at risk for over fertilizing had in common was small lawn size. The largest lawns were sizable at over 30,000 sqft. Most lawns, however, were 11,000 sqft or smaller. At that size, 2 large bags of fertilizer applied in a year will readily result in over-application of nitrogen. Even 1 large bag would over fertilize the median lawn size of 6,500 sqft.

Figure 2.2 perhaps tells the story best of all. The horizontal line indicates a rate of 2.4 lbs N/1,000 sqft/yr, which I will consider to be "at-risk" for over-applying nitrogen. The vertical line indicates the mean lot size of 0.85 acres. Almost all of the lots above 0.85 acres in size were fertilized at rates below being at-risk for over-application. Conversely, almost all of the respondents that I found to have been at-risk for over fertilizing have lot sizes below 1 acre *and* reported purchasing either medium or large bags. The primary issue with over fertilization of lawns appears to be homeowners purchasing bags that are too large for lawns that are too small.

Figure 2.2: Scatter plot of application rates versus lot size by bag size.



Best Management Practices

Tables 2.12 a-f summarize the responses of participants that reported fertilizing their lawn last year. I omitted respondents that did not fertilize last year as field work suggests that those households do not fertilize, in general. Thus, their responses to fertilizer-related BMP questions would not be relevant. Differences between DIY and Contractor homeowners were tested with Pearson's Chi-Squared test.

Sweeping impervious surfaces had the most mixed results. Fully 25% of respondents reported that they or their contractor rarely or never sweep surfaces. However, 40% reported always sweeping surfaces. It appears that fertilizer is more likely to be swept up if a contractor was hired; however, the Chi-Squared test found no significant difference between DIY and Contractor groups ($p=0.18$)

Of the respondents that reported being within 500 feet of a stream or lake, 90% reported never fertilizing along the banks of streams or lakes. Not surprisingly, an even larger number of that group ($n=112$) reported that the BMP was not applicable to them.

Fertilizing before it rains was weighted towards "Sometimes," with 40% of respondents choosing that option. A further 20% of respondents indicated fertilizing before it rains "Usually" or "Always," with most of those respondents being DIY homeowners. The Chi-squared test found the difference between DIY homeowners and Contractor homeowners to be significant ($p<0.01$).

Again, 25% of respondents reported rarely or never mulching their grass while roughly 60% reported usually or always mulching. DIY homeowners are significantly more likely to mulch than contractors are ($p<0.05$).

Nearly 80% of respondents reporting never testing their soil while most respondents reported applying lime on at least a semi-regular basis. However, contractors appear to be responsible for more of the testing and liming than DIY homeowners. The difference between the two groups is significant for both BMPs ($p<0.01$).

Finally, I wanted to find out if respondents tended to be all-or-none in how many BMPs they routinely practiced, or if there was no clear pattern. To do this, I created an index of how many of the BMPs a respondent deemed applicable they practiced. Each BMP variable was simplified to a 0/1 indicator variable. A "0" indicated the respondent selected the worst three of the five options for sweeping, fertilizing stream banks, fertilizing before it rains or mulching grass. A "1" indicated the best two responses were selected. For testing and liming, any level of activity above "Never" was assigned a "1." "Not Applicable" responses were also assigned a "0" in order to ensure their inclusion in the analysis without skewing the results. The final score was the sum of all of the BMP indicators divided by the number of BMPs a given respondent deemed applicable to their self.

Table 2.12 a-f: Summary of responses to 6 best management practices: a) sweep impervious surfaces; b) do not fertilize stream and lake banks; c) do not fertilize before heavy rain; d) mulch grass clippings and leave on lawn; e) test soil; f) lime soil.

a) Sweeps	n	% of Total	% DIY	% Contractor
Never	27	15.9	16.3	15.4
Rarely	15	8.8	8.7	9.0
Sometimes	22	12.9	13.0	12.8
Usually	37	21.8	28.3	14.1
Always	69	40.6	33.7	48.7
NA	25	-	16	9
b) Streams	**n**	**% of Total**	**% DIY**	**% Contractor**
Never	80	89.9	91.7	87.8
Rarely	3	3.4	6.3	0.0
Sometimes	3	0.34	2.1	4.9
Usually	1	1.1	0.0	2.4
Always	2	2.3	0.0	4.9
NA	112	-	62	50
c) B/F Rains	**n**	**% of Total**	**% DIY**	**% Contractor**
Never	28	15.0	14.6	15.5
Rarely	44	23.5	18.5	29.8
Sometimes	75	40.1	35.0	46.4
Usually	29	15.5	21.4	8.3
Always	11	5.9	10.7	0.0
NA	10	-	6	4
d) Mulches	**n**	**% of Total**	**% DIY**	**% Contractor**
Never	36	20.5	11.8	32.4
Rarely	9	5.1	5.9	4.1
Sometimes	30	17.1	17.7	16.2
Usually	34	19.3	23.5	13.5
Always	67	38.1	41.2	33.8
NA	22	-	7	15
e) Testing	**n**	**%**	**% DIY**	**% Contractor**
Never	123	77.9	86.7	66.2
3+ Years	21	13.3	7.8	20.6
Every Other	5	3.2	3.3	2.9
Yearly	9	5.7	2.2	10.3
NA	11	-	5	6
f) Lime	**n**	**%**	**% DIY**	**% Contractor**
Never	43	25.8	33.7	13.9
3+ Years	20	12.0	13.7	9.7
Every Other	26	15.6	17.9	12.5
Yearly	64	38.3	28.4	51.4
By Testing	14	8.4	5.3	12.5
NA	7	-	4	3

All together, homeowners reported practicing about half of applicable BMPs, on average (Table 2.13). Of the 85 respondents that deemed all six BMPs applicable, only two actually reported practicing all six BMPs on a suitably regular basis. The distribution of index scores was normal, with partial compliance being the norm and the extremes of full non-compliance or full compliance being the exception. These patters generally do not change when just looking at the subset of participants that fertilized last year. Only about 25% of homeowners that fertilized last year are practicing at least two-thirds of the BMPs that are applicable to them. Over 50% of respondents reported practicing fewer than half of the BMPs they were responsible for (results not shown).

Finally, I re-did the index using just the three BMPs that most directly related to misapplication of fertilizer: sweeping, fertilizing before it rains, and fertilizing along stream banks. Again, the findings stated heretofore remain largely unchanged (Table 2.13). From this, it is clear that BMPs are universally neglected.

Table 2.13: BMP Compliance Index based on number of applicable BMPs.

	Number Applicable BMPs						
	1	**2**	**3**	**4**	**5**	**6**	**All Together**
All Respondents							
Mean	0.65	0.40	0.37	0.54	0.47	0.57	0.50
# Full Compliance	17	2	1	5	2	2	29
n	26	21	66	52	117	85	367
Fertilized Last Year							
Mean	0.67	0.5	0.43	0.57	0.51	0.61	0.54
# Full Compliance	4	0	0	4	1	2	11
n	6	7	18	33	75	61	200
Fertilized and Misapplication							
Mean	0.33	0.49	0.67	-	-	-	0.55
# Full Compliance	6	19	24	-	-	-	49
n	18	91	82	-	-	-	191

Grass Types and Application Months

Responses to the grass type questions were somewhat chaotic. With effort, I was able to reduce respondents to one of six categories: 50/50 cool season and warm season grass; 75/25 cool season and warm season grass; 25/75 cool season and warm season grass; all cool season grass; all warm season grass; or did not know (Table 2.14). Doing this revealed that cool season grasses dominate in the county only where mixes of cool and warm season grasses occur. Otherwise, the two appear to be equally common. As a side note, home visits have revealed that warm and cool season grasses often occur mixed together, not separated into different sections of the lawn.

Cool season grasses also appear to be significantly more popular in HOAs (Chi-squared $p<0.01$). Further, households with in-ground sprinklers appear to almost exclusively have cool season grass, with 33 out of 39 reporting having all or mostly cool season grasses.

Table 2.14: Number and percentage of homeowners that reported different mixes of grass types.

Grass	n	%
50/50 C/W	31	11.3
75/25 C/W	58	21.1
25/75 C/W	20	7.3
100 Cool	81	29.5
100 Warm	85	30.9
IDK	77	-
Total	352	100

Cool season grasses were primarily fertilized during the correct times of year (Figure 2.3). Only about 20% of respondents that fertilized their lawn last year indicated that they fertilize in a month that is not the correct season for cool season grasses. Most of those that fertilized in the wrong month, however, fertilized in April, which is only marginally out of season for cool grasses. More importantly, the worst months to fertilize in- June, July and August- saw little activity.

Nearly 30% of participants that fertilized their lawn last year fertilized out of season for warm season grasses. Most of the warm season grass fertilization events occurred during the wrong months of the year, either too early or too late in the season (Figure 2.4).

Test Results

Only 20 out of the 333 participants that that took the test questions got all 3 correct (Table 2.15). The vast majority of participants answered “I don’t know” to the rate calculation question and the NPK question. Where participants did answer those two questions, they were generally able to answer them correctly. Incorrect answers to the NPK question were mainly due to confusion over P (Phosphorus) and K (Potassium). Incorrect responses to the rate question were mainly due to low-balling. The true/false question had better responses, overall.

Table 2.15: Summary of responses to test questions.

Question	Correct	Incorrect	IDK
True/False	160	73	100
True/False (Fertilized only)	107	34	36
Application Rate	26	21	272
NPK	70	33	225
All Correct	20	313	-

Home Visits

A total of 31 home visits were conducted during June and July. Soil samples were not taken for three lawns due to small lawn size. Soils, on average, were below the minimum recommended pH of 5.8 (Table 2.16). Only two lawns were actually within the

Figure 2.3: Months in which cool season grasses were fertilized. *(blue- correct month; black- incorrect month; orange- did not know)*

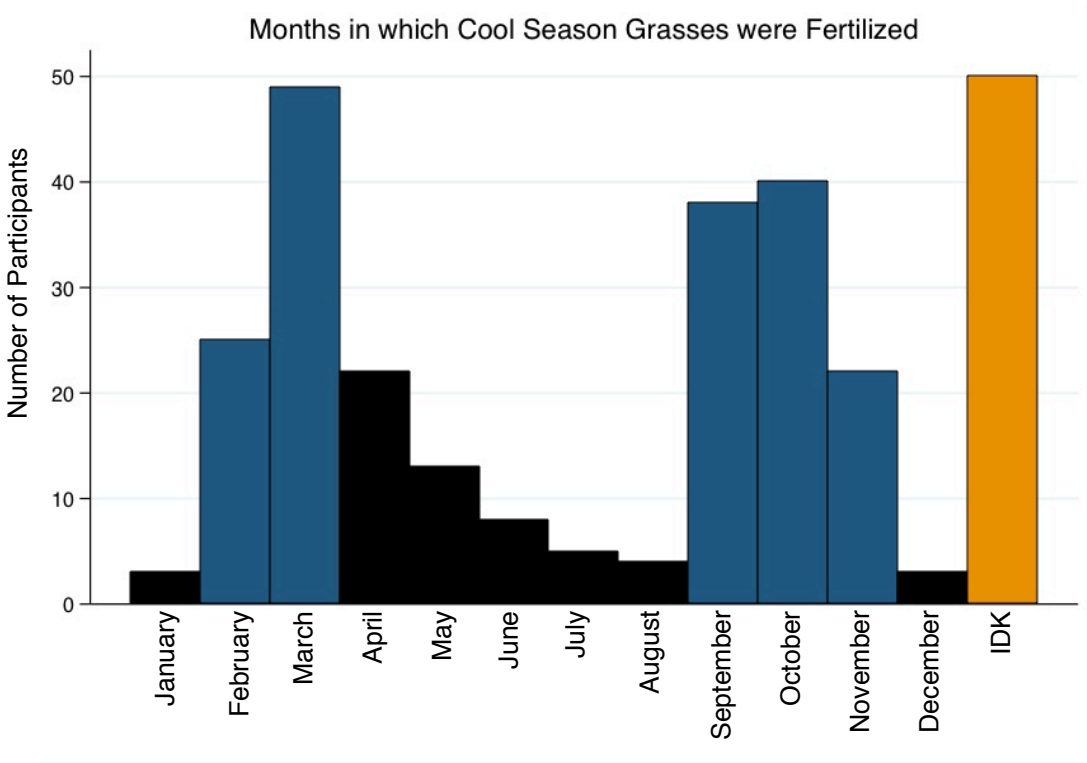
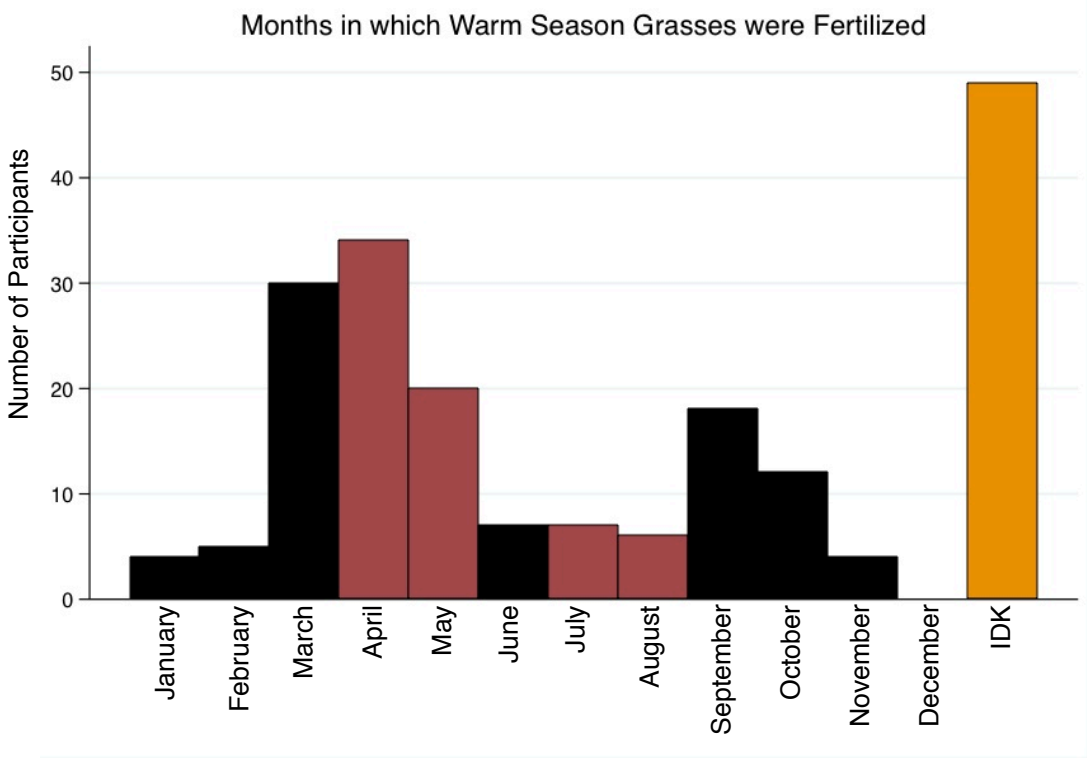


Figure 2.4: Months in which warm season grasses were fertilized. *(red- correct month; black- incorrect month; orange- did not know)*



target range for available phosphorus (between 50 and 70), while 4 were well above it (86, 130, 197, and 204) and the rest were well below it. The potassium levels were much better with 10 lawns within the target range. The sampling methodology did not allow for an analysis of soil physical properties.

Table 2.17 lists the number of DIY, contractor and non-fertilizing participants along with the mean values for several different attributes for each group. Homeowners that hired contractors generally had the nicest lawns, primarily due to better weed control. Many homeowners that did not fertilize last year still had fair lawns due to coverage and greenness. Only available phosphorus was consistently higher in lawns that were fertilized.

Table 2.16: Summary of results from home visits for all lawns.

	Mean	Min	Max
Quality	2.8	1	5
pH	5.8	4.9	6.7
CEC	13.0	4.4	23.3
P-Index	46	7	204
K-Index	55	22	103
Area	9,300	552	32,086

Table 2.17: Means of results from home visits by fertilized type.

	DIY	Contractor	None
Fertilized (n)	10	7	14
Quality	3	4	2.1
pH	5.8	6.0	5.8
CEC	13.9	11.8	12.8
P-Index	65	57	24
K-Index	68	46	50
Area	11,200	12,500	6,300

Of the 14 homeowners that reported not fertilizing last year, 10 stated that they had never fertilized their lawn. Of the 4 that had fertilized their lawns in the past (but not last year), 3 reported that they planned to fertilize again at some point in the future while 1 person reported planning on letting their lawn go natural. Of the 10 participants that reported having never fertilized their lawn, 1 said they would in the future, 2 said they were unsure, while the rest said that they never will fertilize their lawns. Explanations for not fertilizing last year ranged from environmental concerns to plain honest laziness. The most common explanation, however, was to simply let the lawn grow naturally.

APPENDICES

Appendix A - Surveys

Full Paper Survey

ID #: _____

SECTION A

1. Do you have a lawn that you are responsible for maintaining?

- ❍ Yes
- ❍ No

If you selected No, please skip to Section B on Page 8.

2. Was your lawn fertilized at least once last year?

- ❍ Yes, I did it my self.
- ❍ Yes, I paid an outside contractor.
- ❍ No, my lawn was not fertilized last year.

3. How important is having an attractive lawn to you?

- ❍ Very Unimportant
- ❍ Unimportant
- ❍ Neutral
- ❍ Important
- ❍ Very Important

4. Do you belong to a homeowners association (HOA) or neighborhood association (NA)?

- ❍ Yes, a HOA
- ❍ Yes, a NA
- ❍ No (Skip to Question 6)

5. Does your HOA or NA have strict guidelines for lawn care?

- ❍ Yes and I follow them
- ❍ Yes but I do not follow them
- ❍ No

6. Are you familiar with any Best Management Practices related to lawn care?

- ❍ Yes
- ❍ No
- ❍ It sounds familiar

7. Would you like to know more about the best way to fertilize your lawn and garden.

- ❍ Yes
- ❍ No

Please answer the following questions based on your behaviors or the behaviors of the lawn care company you contract with, as appropriate.

8. I/My contractor sweeps fertilizer off of the road, driveway and/or sidewalk and back into my lawn.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

9. I/My Contractor spreads fertilizer along the banks of streams or other bodies of water.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

10. I/My contractor fertilizes the lawn just before it rains.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

11. I/My contractor mulches grass clippings and leaves them in the yard.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

12. I/My contractor tests the soil for my lawn.

- ❍ Never
- ❍ Every 3 years or less
- ❍ Every other year
- ❍ Every year or more
- ❍ Not Applicable

13. I/My contractor applies lime to the lawn.
- ❍ Never
- ❍ Every 3 years or less
- ❍ Every other year
- ❍ Every year or more
- ❍ When testing says I should
- ❍ Not Applicable

14. What method did you/your contractor use to apply fertilizer the last time you applied fertilizer to your lawn?
- ❍ Drop spreader
- ❍ Broadcast Spreader
- ❍ Hand Spreader
- ❍ Spread by Hand
- ❍ Other _____

15. When drought restrictions are NOT in effect, how frequently do you water your lawn?
- ❍ Daily
- ❍ Every other day
- ❍ Twice a week
- ❍ Once a week
- ❍ 2-3 times a month
- ❍ Never
- ❍ Not Applicable

16. Do you have an in-ground sprinkler system?
- ❍ Yes
- ❍ No (Skip to Question 18)

17. Is your sprinkler system set on an automatic timer?
- ❍ Yes
- ❍ No

Please answer the following questions with regards to your own behavior.

18. When I self-apply fertilizer in my yard, I read the label on the back of the fertilizer bag.
- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

19. When I self-apply fertilizer in my yard, I follow the directions on the back of the fertilizer bag

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

Answer Questions 20 if you hired a contractor last year to fertilize your lawn.

20. I pay attention to how much fertilizer the contractor applies to my lawn.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All the Time
- ❍ I Can't

The following questions will help you to estimate the amount and type of grass you have in your lawn, as well as how frequently you fertilize it.

21. Roughly how much of your lawn is still green in the winter (cool season grasses, for example fescue, kentucky bluegrass)?

- ❍ 25% or less
- ❍ 25 to 50%
- ❍ 50 to 75%
- ❍ 75% or more
- ❍ None
- ❍ I don't know

22. In what months did you/your contractor apply fertilizer to your cool-season grass this past year?

- ❑ January
- ❑ February
- ❑ March
- ❑ April
- ❑ May
- ❑ June
- ❑ July
- ❑ August
- ❑ September
- ❑ October
- ❑ November
- ❑ December
- ❑ I Don't Know
- ❑ Not Applicable

23. How much of your lawn turns brown in the winter (warm season grasses, for example bermudagrass, centipedegrass, zoysiagrass)?

- ❍ 25% or less
- ❍ 25 to 50%
- ❍ 50 to 75%
- ❍ 75% or more
- ❍ None
- ❍ I don't know

24. In what months did you/your contractor apply fertilizer to your warm-season grass this past year?

- ❑ January
- ❑ February
- ❑ March
- ❑ April
- ❑ May
- ❑ June
- ❑ July
- ❑ August
- ❑ September
- ❑ October
- ❑ November
- ❑ December
- ❑ I Don't Know
- ❑ Not Applicable

25. Is there any additional information that you would like for us to know about the questions you have answered thus far? Additional space is provided at the end of the survey.

_____
_____
_____
_____

To the best of your ability, please fill out the following information with regards to your fertilizer purchase(s) last year.

26. Approximately what size bags of lawn fertilizer did you typically buy?

- ❑ Small (13-20 lbs or 5,000 square feet of coverage)
- ❑ Medium (~30 lbs or 10-12,000 square feet of coverage)
- ❑ Large (40 to 50 lbs or 15,000 square feet of coverage)
- ❑ Exactly ____ lbs for all bags
- ❑ Do not recall

27. Approximately how many bags of lawn fertilizer did you purchase last year?

- ❍ 1 bag
- ❍ 2 bags
- ❍ 3 bags
- ❍ 4 bags
- ❍ 5 bags
- ❍ 6 bags
- ❍ 7 bags
- ❍ 8 bags
- ❍ ____ bags
- ❍ Do not recall

28. How much of a bag did you typically apply in one application?

- ❍ All of it
- ❍ 3/4 of the bag
- ❍ 1/2 of the bag
- ❍ 1/4 of the bag
- ❍ ____ lbs
- ❍ Do not recall

29. What kind of fertilizer did you use on your lawn? Please select all that apply. (You may wish to reference the list of fertilizer brands and types provided at the end of the survey).

GENERIC

- ❑ Lawn Fertilizer (21-1-6)
- ❑ Weed and Feed (28-1-7)
- ❑ Starter Fertilizer (20-25-7)
- ❑ Winterizer (25-1-12)
- ❑ Organic Fertilizer (5-2-0)
- ❑ General Purpose (10-10-10)
- ❑ General Purpose (17-17-17)

EXPERT GARDENER

- ❑ Lawn Fertilizer (29-0-4)
- ❑ Weed and Feed (28-0-3)

LESCO

- ❑ Professional Turf Fertilizer (24-0-11)
- ❑ Professional Weed and Feed (18-0-9)
- ❑ Professional Starter (18-25-12)
- ❑ Professional Fall/Winter Fertilizer (18-0-18)

MILOGRANITE

- ❑ Organic Fertilizer (5-2-0)

PEMINGTON

- ❑ Signature Starter (18-24-6)

SCOTTS

- ❑ Natural Lawn Feed (11-2-2)
- ❑ Bonus S Weed and Feed (29-1-10)
- ❑ Southern Green Max with Iron (26-0-2)
- ❑ Turf Builder Southern Lawn Food (32-0-10)
- ❑ Turf Builder Plus 2 Weed and Feed (28-1-4)
- ❑ Turf Builder Starter (24-25-4)
- ❑ Turf Builder Winterguard (32-0-10)
- ❑ Turf Builder Winterguard Plus Weed and Feed (26-2-12)

STA-GREEN

- ❑ Lawn Fertilizer (29-0-5)
- ❑ Weed and FEed (28-0-4)
- ❑ Winterizer (22-0-14)

VIGORO

- ❑ Lawn Fertilizer (29-0-4)
- ❑ Ultra Turf (30-0-4)
- ❑ Super Green (35-0-5)
- ❑ Weed and Feed (28-0-3)
- ❑ Starter (20-27-5)

30. Is there any additional information you would like to provide us about your fertilizer purchases last year? Additional space is provided at the end of the survey.

_____

_____

_____

Answer Questions 31 and 32 if you hired a contractor last year to fertilize your lawn.

31. How much did you pay for lawn care services last year?

$_____

32. What services were included in your lawn care package? (Please select all that apply)

- ❑ Fertilizer Application
- ❑ Weed Control
- ❑ Lawn Trimming
- ❑ Edging
- ❑ Leaf and Limb Removal
- ❑ Aeration
- ❑ Overseeding
- ❑ Pruning
- ❑ White Grub Control
- ❑ Organic Only Option
- ❑ Other _____

The following questions will help you to estimate the size of your lawn.

33. What is the approximate size of your lot?

_____ square feet / acres (circle one)

34. About how much of your lot is mowed?

- ❍ 1/10 (10%)
- ❍ 1/4 (25%)
- ❍ 1/3 (33%)
- ❍ 1/2 (50%)
- ❍ 2/3 (66%)
- ❍ 3/4 (75%)
- ❍ 9/10 (90%)
- ❍ None

35. Would you be willing to allow the researcher to come to your house and measure your lawn size?

- ❍ Yes.
- ❍ No.
- ❍ Maybe.

36. Would you be willing to allow the researcher to come to your house and take a soil sample? The results will be freely shared with you.

- ❍ Yes.
- ❍ No.
- ❍ Maybe.

37. Please indicate the best way for the researcher to get in touch with you and arrange a visit. The information you provide will be permanently deleted from the sample data once the researcher has reached you or 1 month after completion of the survey. Your information will never, under any circumstances, be shared with a third party. You will not be contacted for any other purpose than to arrange the home visit.

- ❍ Email _____
- ❍ Phone _____
- ❍ Other _____

The purpose of the following questions is to assess your knowledge about fertilizer application. It is perfectly O.K. to say "I don't know" as most people are not familiar with these concepts.

38. True or False: Applying more fertilizer will make my lawn greener.

- ❍ True
- ❍ False
- ❍ I don't know

39. John wants to apply 1 lb of Nitrogen to his 1,000 square foot lawn. He purchased a 20 lb bag of 10-1-5 fertilizer for the application. About how much of the bag should John apply to his lawn?

- ❍ All of the bag (20 lbs)
- ❍ 3/4 of the bag (15 lbs)
- ❍ 1/2 of the bag (10 lbs)
- ❍ 1/4 of the bag (5 lbs)
- ❍ I don't know.

40. What do the numbers "10 - 1 - 5" on John's bag mean?

- ❍ The bag contains 10 pounds of Nitrogen, 1 pound of Potassium, and 5 pounds of Phosphorus.
- ❍ The bag is 10% Nitrogen, 1% Phosphorus, and 5% Potassium.
- ❍ The bag is 10% Phosphorus, 1% Nitrogen, and 5% Potassium.
- ❍ The bag is 10% Nitrogen, 1% Potassium, and 5% Phosphorus.
- ❍ I don't know

SECTION B

41. Does your house have a septic system?

- ❍ Yes
- ❍ No
- ❍ I don't know

If you selected No, then skip to Section C on Page 11.

42. Are you currently experiencing any of the following problems in your lawn or home?

- ❑ Wet patches in the yard near the septic system.
- ❑ Slow drainage of sinks, bathtubs and other pipes in the house.
- ❑ Sewage odors in or near the house.
- ❑ None

If you selected I don't know for Question 41, then skip to Section C on Page 11.

43. Is your septic system permitted by the State of North Carolina or by Durham County?

- ❍ State of North Carolina
- ❍ Durham County
- ❍ I don't know.

44. How old is your septic system? You may estimate the age if you are not exactly sure.

- ❍ Exactly ____ years old
- ❍ At least ____ years old
- ❍ I don't know.

45. How large is your septic tank?

- ❍ 900 gallons
- ❍ 1,000 gallons
- ❍ 1,250 gallons
- ❍ 1,500 gallons
- ❍ Other _____ gallons
- ❍ I don't know.

46. When was your septic system last pumped?

- ❍ Last Year
- ❍ 2 years ago
- ❍ 3 years ago
- ❍ 4 years ago
- ❍ 5 years ago
- ❍ More than 5 years ago
- ❍ Never
- ❍ I don't Know

47. When was your septic system last inspected?

- ❍ Last year
- ❍ 2 years ago
- ❍ 3 years ago
- ❍ 4 years ago
- ❍ 5 years ago
- ❍ More than 5 years ago
- ❍ Never
- ❍ I don't know

48. Have you had to replace your septic system in the past 5 years?

- ❍ Yes
- ❍ No

Answer Questions 49, 50 and 51 if you had to replace your septic system.

49. Approximately how much did the system cost you? Include all costs such as removal and disposal of old system, purchase of the new system, installation, and other costs associated with replacing your septic system.

$_____,_____

50. Approximately how long did the replacement take?

- ❍ _____ days
- ❍ _____ weeks
- ❍ I don't know

51. How troublesome was the replacement process?

- ❍ Extremely Troublesome
- ❍ Troublesome
- ❍ Troublesome but Tolerable
- ❍ Few Troubles
- ❍ No Trouble at all

52. Is there any additional information you would like to provide us about your septic system practices? Additional space is provided at the end of the survey.

_____
_____
_____
_____
_____

53. Purchasing a new septic system to replace a failed system costs between $5,000 and $35,000, with most systems typically being $10-15,000. Routine pumping (every 3 to 5 years) can prolong the life of a septic system by helping to keep it clear of the solids that often clog systems and cause them to fail.

Would you be willing to pay $50 per year to reduce the risk of having to purchase a new septic system through pumping?

- ❍ Yes
- ❍ No

SECTION C

54. Which types of slope are present on your property? Of the types that are present, which is the most dominant and which is the least dominant type?

Slope	Present on Property	Most Dominant	Least Dominant
Very steep slope	❑	❍	❍
Steep slope	❑	❍	❍
Gentle slope	❑	❍	❍
Flat (top of hill)	❑	❍	❍
Flat (bottom of hill)	❑	❍	❍

55. Where is the nearest stream to your property? Streams include creeks, ditches, streams and rivers that are flowing year-round, and intermittent streams that only flow during heavy rain events.

❍ A stream runs through my property.
❍ A stream runs along the border of my property.
❍ A stream runs within 100 feet of my property.
❍ A stream runs within 500 feet of my property.
❍ There are no streams near my property (500 feet or more away).

56. Where is the nearest lake or pond to your property?

❍ A lake/pond is on my property.
❍ A lake/pond borders my property.
❍ A lake/pond is within 100 feet of my property.
❍ A lake/pond is within 500 feet of my property.
❍ There are no lakes or ponds near my property (500 feet or more away).

SECTION D

57. How many people reside at this address?

_____ people

58. How many years have you been living at this address?

_____ years

59. Do you own or rent the property?

❍ I own
❍ I am a renter
❍ No Response

60. How old are you in years? You may round to the nearest 5 years.

_____ years

61. What is your highest level of educational attainment?

- ❍ Less than high school education
- ❍ Completed high school or GED
- ❍ Some college
- ❍ Bachelors degree
- ❍ Graduate Degree
- ❍ Some technical school
- ❍ Completed technical school
- ❍ No response

62. Roughly, what is your annual household income?

- ❍ $20,000 per year or less
- ❍ $20,001 - $40,000 per year
- ❍ $40,001 - $60,000 per year
- ❍ $60,001- $80,000 per year
- ❍ $80,001 - $100,000 per year
- ❍ $100,001 - $120,000 per year
- ❍ $120,001 - $140,000 per year
- ❍ $140,001 per year or more
- ❍ No Response

----------END OF SURVEY ----------

THANK YOU FOR PARTICIPATING!

At this point, simply place this survey in the self addressed, business-reply envelope we have provided for you and place in the mailbox.

Results will be available in July on the Durham County website.

Feel free to use this space for any additional questions, comments or concerns.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Abridged Version
ID #: _____

SECTION A

1. Do you have a lawn that you are responsible for maintaining?
- ❍ Yes
- ❍ No

If you selected No, please skip to Section B on Page 4.

2. Was your lawn fertilized at least once last year?
- ❍ Yes, I did it my self.
- ❍ Yes, I paid an outside contractor.
- ❍ No, my lawn was not fertilized last year.

3. How important is having an attractive lawn to you?
- ❍ Very Unimportant
- ❍ Unimportant
- ❍ Neutral
- ❍ Important
- ❍ Very Important

4. Do you belong to a homeowners association (HOA) or neighborhood association (NA)?
- ❍ Yes, a HOA
- ❍ Yes, a NA
- ❍ No (Skip to Question 6)

5. Does your HOA or NA have strict guidelines for lawn care?
- ❍ Yes and I follow them
- ❍ Yes but I do not follow them
- ❍ No

Please answer the following questions based on your behaviors or the behaviors of the lawn care company you contract with, as appropriate.

6. I/My contractor sweeps fertilizer off of the road, driveway and/or sidewalk and back into my lawn.
- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

7. I/My Contractor spreads fertilizer along the banks of streams or other bodies of water.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

8. I/My contractor fertilizes the lawn just before it rains.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

9. I/My contractor mulches grass clippings and leaves them in the yard.

- ❍ Never
- ❍ Rarely
- ❍ Sometimes
- ❍ Often
- ❍ All of the Time
- ❍ Not Applicable

The following questions will help you to estimate the amount and type of grass you have in your lawn, as well as how frequently you fertilize it.

10. Roughly how much of your lawn is still green in the winter (cool season grasses, for example fescue, kentucky bluegrass)?

- ❍ 25% or less
- ❍ 25 to 50%
- ❍ 50 to 75%
- ❍ 75% or more
- ❍ None
- ❍ I don't know

11. In what months did you/your contractor apply fertilizer to your cool-season grass this past year?

- ❑ January
- ❑ February
- ❑ March
- ❑ April
- ❑ May
- ❑ June
- ❑ July
- ❑ August
- ❑ September
- ❑ October
- ❑ November
- ❑ December
- ❑ I Don't Know
- ❑ Not Applicable

1**2.** How much of your lawn turns brown in the winter (warm season grasses, for example bermudagrass, centipedegrass, zoysiagrass)?

- ❍ 25% or less
- ❍ 25 to 50%
- ❍ 50 to 75%
- ❍ 75% or more
- ❍ None
- ❍ I don't know

13. In what months did you/your contractor apply fertilizer to your warm-season grass this past year?

- ❑ January
- ❑ February
- ❑ March
- ❑ April
- ❑ May
- ❑ June
- ❑ July
- ❑ August
- ❑ September
- ❑ October
- ❑ November
- ❑ December
- ❑ I Don't Know
- ❑ Not Applicable

IF you fertilize your own lawn last year, to the best of your ability, please fill out the following information with regards to your fertilizer purchase(s) last year.

14. Approximately what size bags of lawn fertilizer did you typically buy?

- ❑ Small (13-20 lbs or 5,000 square feet of coverage)
- ❑ Medium (~30 lbs or 10-12,000 square feet of coverage)
- ❑ Large (40 to 50 lbs or 15,000 square feet of coverage)
- ❑ Exactly ____ lbs for all bags
- ❑ Do not recall

15. Approximately how many bags of lawn fertilizer did you purchase last year?

- ❍ 1 bag
- ❍ 2 bags
- ❍ 3 bags
- ❍ 4 bags
- ❍ 5 bags
- ❍ 6 bags
- ❍ 7 bags
- ❍ 8 bags
- ❍ ____ bags
- ❍ Do not recall

16. How much of a bag did you typically apply in one application?

- ❍ All of it
- ❍ 3/4 of the bag
- ❍ 1/2 of the bag
- ❍ 1/4 of the bag
- ❍ ____ lbs
- ❍ Do not recall

17. What kind of fertilizer did you use on your lawn? Please select all that apply.

GENERIC

- ❑ Lawn Fertilizer (21-1-6)
- ❑ Weed and Feed (28-1-7)
- ❑ Starter Fertilizer (20-25-7)
- ❑ Winterizer (25-1-12)
- ❑ Organic Fertilizer (5-2-0)
- ❑ General Purpose (10-10-10)
- ❑ General Purpose (17-17-17)

The following questions will help you to estimate the size of your lawn.

18. What is the approximate size of your lot?

_____ square feet / acres (circle one)

19. About how much of your lot is mowed?

- ❍ 1/10 (10%)
- ❍ 1/4 (25%)
- ❍ 1/3 (33%)
- ❍ 1/2 (50%)
- ❍ 2/3 (66%)
- ❍ 3/4 (75%)
- ❍ 9/10 (90%)
- ❍ None

SECTION B

20. Does your house have a septic system?

- ❍ Yes
- ❍ No
- ❍ I don't know

If you selected No, then skip to Section C on Page 5.

21. Are you currently experiencing any of the following problems in your lawn or home?

- ❑ Wet patches in the yard near the septic system.
- ❑ Slow drainage of sinks, bathtubs and other pipes in the house.
- ❑ Sewage odors in or near the house.
- ❑ None

If you selected I don’t know for Question 20, then skip to Section C on Page 5.

22. Is your septic system permitted by the State of North Carolina or by Durham County?

- ❍ State of North Carolina
- ❍ Durham County
- ❍ I don't know.

23. How old is your septic system? You may estimate the age if you are not exactly sure.

- ❍ Exactly ____ years old
- ❍ At least ____ years old
- ❍ I don't know.

24. When was your septic system last pumped?

- ❍ Last Year
- ❍ 2 years ago
- ❍ 3 years ago
- ❍ 4 years ago
- ❍ 5 years ago
- ❍ More than 5 years ago
- ❍ Never
- ❍ I don't Know

25. When was your septic system last inspected?

- ❍ Last year
- ❍ 2 years ago
- ❍ 3 years ago
- ❍ 4 years ago
- ❍ 5 years ago
- ❍ More than 5 years ago
- ❍ Never
- ❍ I don't know

SECTION C

26. How many people reside at this address?

_____ people

27. How many years have you been living at this address?

_____ years

28. Do you own or rent the property?

- ❍ I own
- ❍ I am a renter
- ❍ No Response

29. How old are you in years? You may round to the nearest 5 years.

_____ years

30. What is your highest level of educational attainment?

- ❍ Less than high school education
- ❍ Completed high school or GED
- ❍ Some college
- ❍ Bachelors degree
- ❍ Graduate Degree
- ❍ Some technical school
- ❍ Completed technical school
- ❍ No response

31. Roughly, what is your annual household income?

- ❍ $20,000 per year or less
- ❍ $20,001 - $40,000 per year
- ❍ $40,001 - $60,000 per year
- ❍ $60,001- $80,000 per year
- ❍ $80,001 - $100,000 per year
- ❍ $100,001 - $120,000 per year
- ❍ $120,001 - $140,000 per year
- ❍ $140,001 per year or more
- ❍ No Response

----------END OF SURVEY ----------

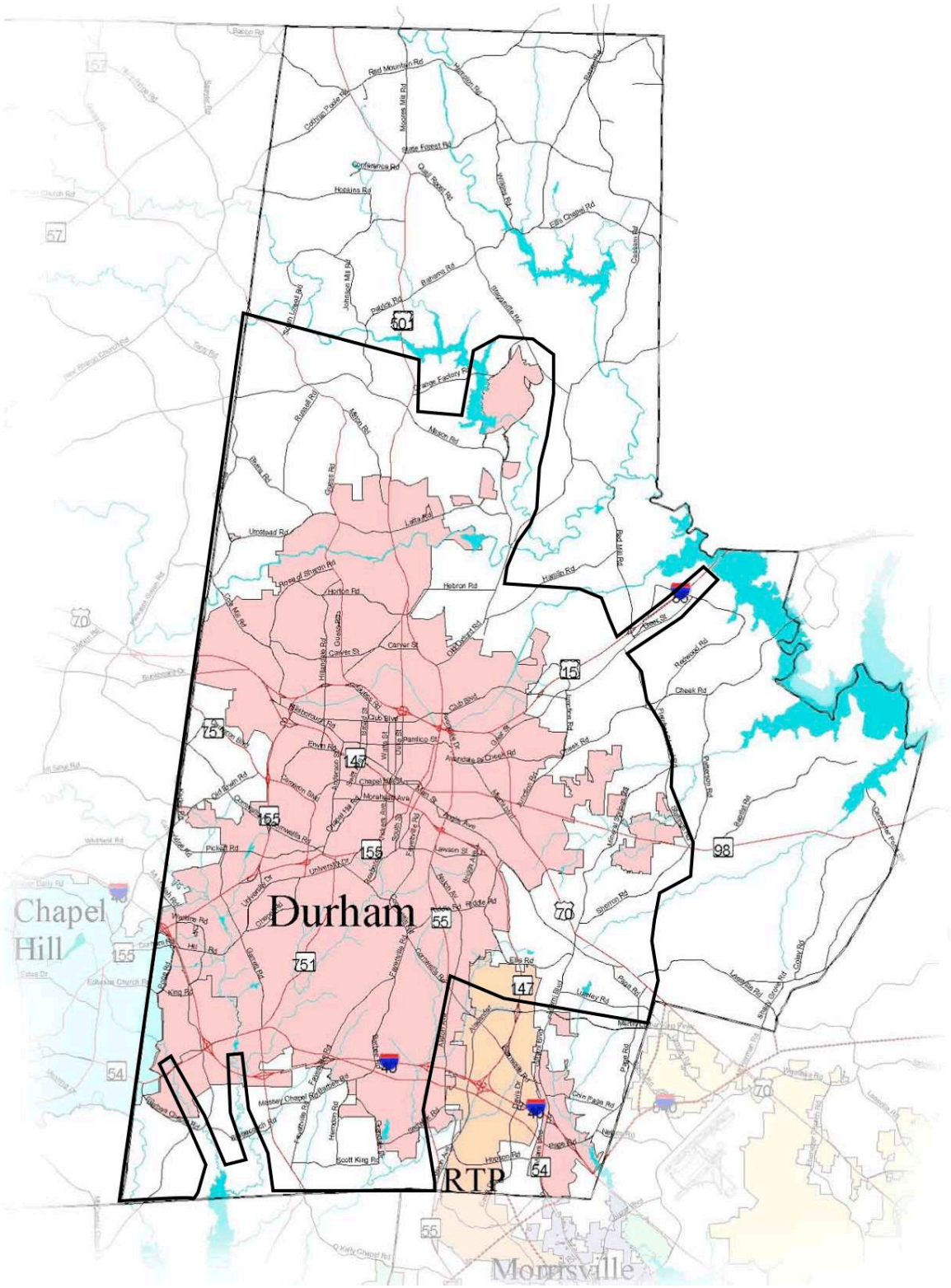
THANK YOU FOR PARTICIPATING!

At this point, simply place this survey in the self addressed, business-reply envelope we have provided for you and place in the mailbox.

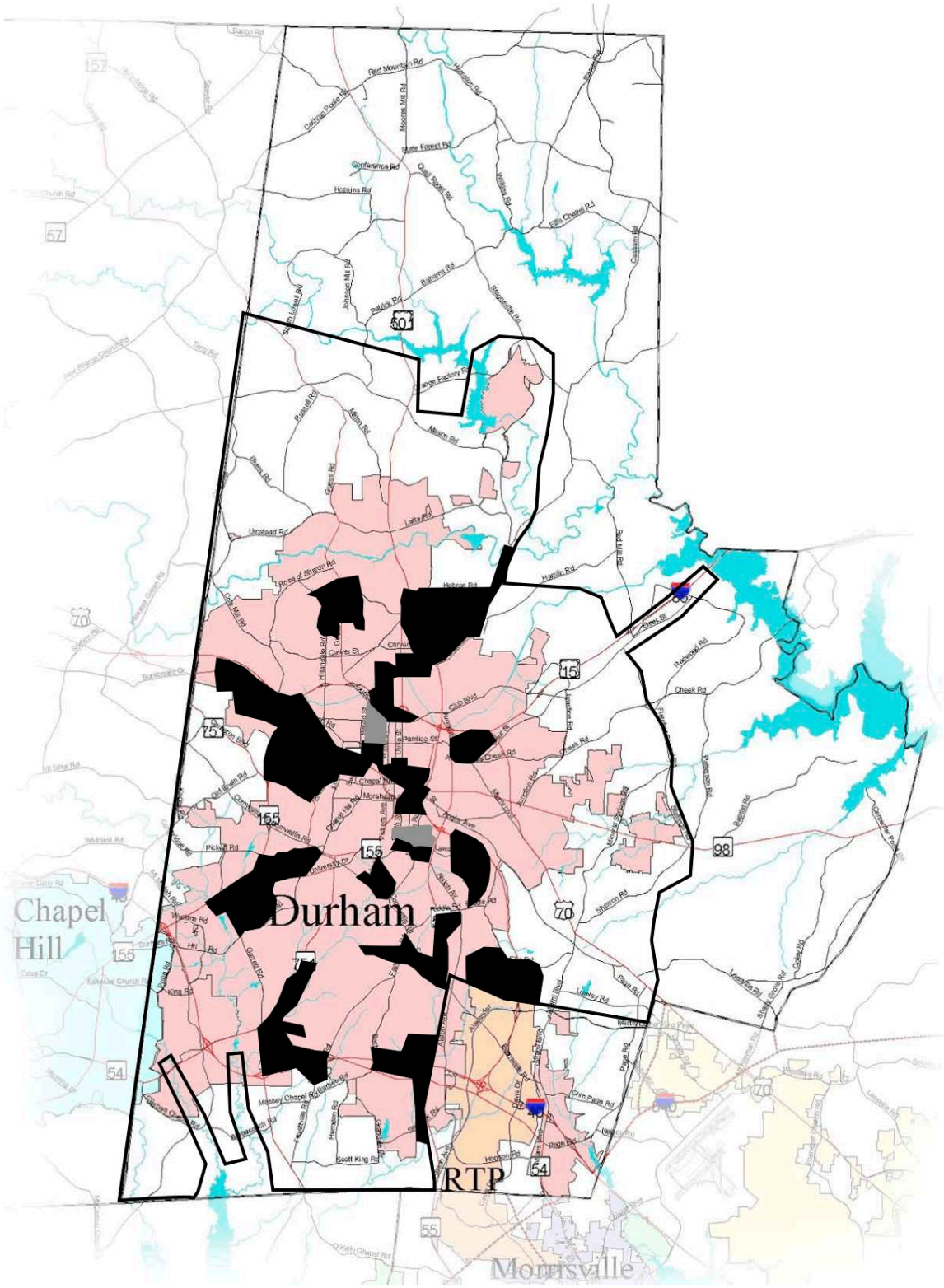
Results will be available in July on the Durham County website.

Feel free to use this space for any additional questions, comments or concerns.

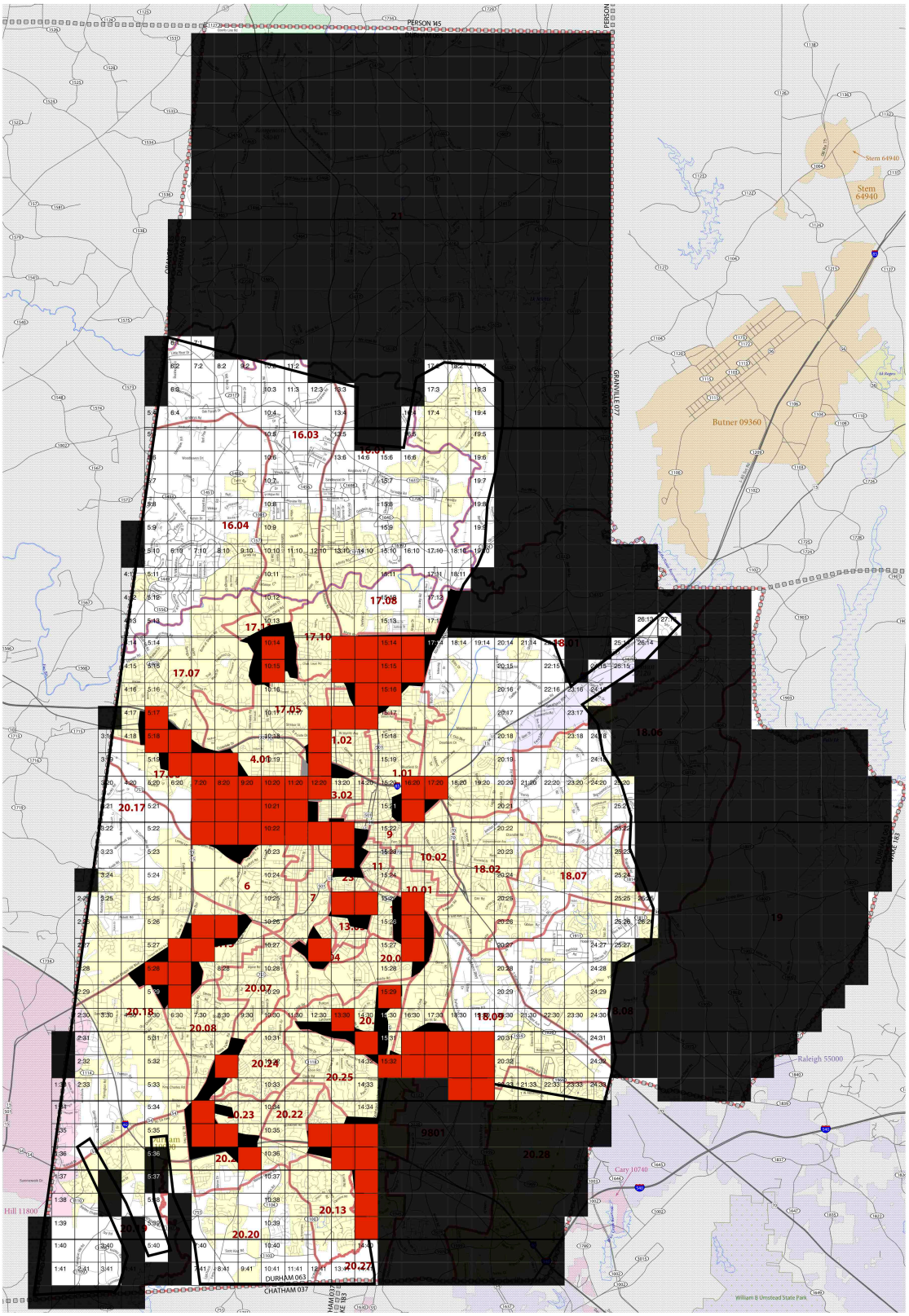
Appendix B - Maps

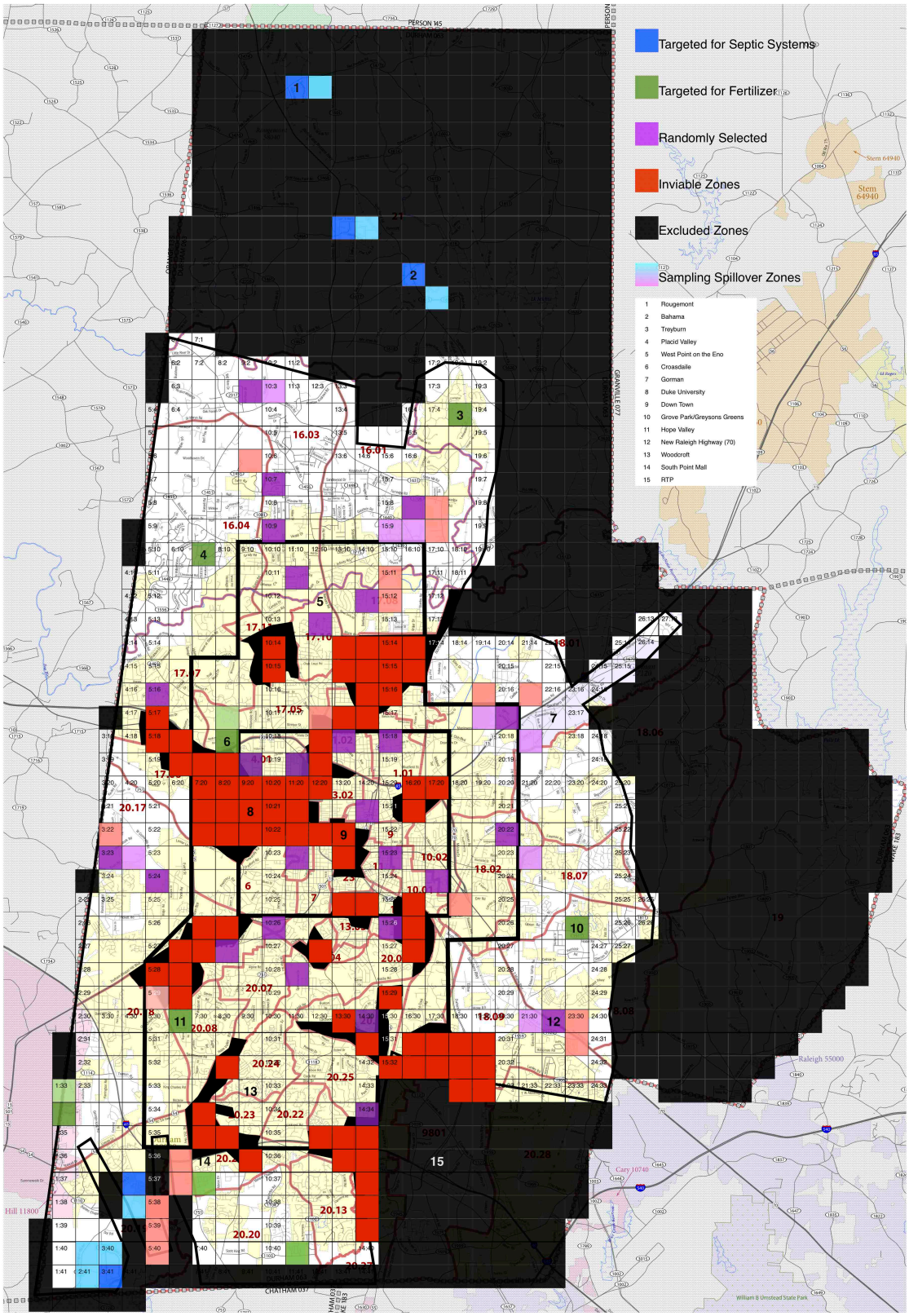


t



u


PERSON 145
GRANVILLE 077
Stem 64940
Butner 09360
16.03
16.04
17.08
17.10
17.07
17.05
1.02
4.01
1.01
3.02
20.17
10.02
18.02
18.07
10.01
20.07
20.18
20.08
18.09
20.24
20.25
20.23
20.22
9801
20.28
20.13
20.20
20.27
Raleigh 55000
Cary 10740
Hill 11800
DURHAM 063
CHATHAM 037
William B Umstead State Park


Targeted for Septic Systems
Targeted for Fertilizer
Randomly Selected
Inviable Zones
Excluded Zones
Sampling Spillover Zones
1 Rougemont
2 Bahama
3 Treyburn
4 Placid Valley
5 West Point on the Eno
6 Croasdaile
7 Gorman
8 Duke University
9 Down Town
10 Grove Park/Greysons Greens
11 Hope Valley
12 New Raleigh Highway (70)
13 Woodcroft
14 South Point Mall
15 RTP
PERSON 145
GRANVILLE 077
CHATHAM 037
Raleigh 55000
Cary 10740
Hill 11800
William B Umstead State Park

W

Rectangle (BxH)

Added:

B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____ +
B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____ == _____

Subtracted:

B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____
B___*H___= _____ + B___*H___= _____ + B___*H___= _____ + B___*H___= _____ == _____

Triangle (1/2 BxH)

Added:

1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ +
1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ == _____

Subtracted:

1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ +
1/2 B___*H___= _____ + 1/2 B___*H___= _____ + 1/2 B___*H___= _____ == _____

Trapezoid 1/2 (b1+b2)*h

Added:

1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ +
1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ == _____

Subtracted:

1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ +
1/2 (B1___+B2___)*H___= _____ + 1/2 (B1___+B2___)*H___= _____ == _____

Circle (π r^2)

Added:

π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ +
π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ == _____

Subtracted:

π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ +
π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ + π R___*R___=_____ == _____

Oval (π AxB)
Added:
π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ +
π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ == _____

Subtracted:
π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ +
π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ + π A___*B___=_____ == _____

Half-Circle (1/2 π r^2)
Added:
1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ +
1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ == _____

Subtracted:
1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ +
1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ + 1/2 π R___*R___=_____ == _____

Total:
Added:
Rectangle_____ + Triangle_____ + Trapezoid_____ + Circle_____ + Oval_____ + H. Circle_____

Subtracted:
Rectangle_____ + Triangle_____ + Trapezoid_____ + Circle_____ + Oval_____ + H. Circle_____

Add_____ - Subtract_____ = _____ sq ft

Notes:
Lawn Quality: Excellent Good Fair Poor Terrible

Grass Type: Fescue/Kentucky Blue Bermuda Zoysia Clover

Other: _____
_____
_____

Appendix Z - Z-Score Tables

Z Score Table- chart value corresponds to area below z score.

z	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.00
–3.4	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
–3.3	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005
–3.2	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007
–3.1	0.0007	0.0007	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0010
–3.0	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012	0.0013	0.0013	0.0013
–2.9	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0018	0.0018	0.0019
–2.8	0.0019	0.0020	0.0021	0.0021	0.0022	0.0023	0.0023	0.0024	0.0025	0.0026
–2.7	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
–2.6	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0043	0.0044	0.0045	0.0047
–2.5	0.0048	0.0049	0.0051	0.0052	0.0054	0.0055	0.0057	0.0059	0.0060	0.0062
–2.4	0.0064	0.0066	0.0068	0.0069	0.0071	0.0073	0.0075	0.0078	0.0080	0.0082
–2.3	0.0084	0.0087	0.0089	0.0091	0.0094	0.0096	0.0099	0.0102	0.0104	0.0107
–2.2	0.0110	0.0113	0.0116	0.0119	0.0122	0.0125	0.0129	0.0132	0.0136	0.0139
–2.1	0.0143	0.0146	0.0150	0.0154	0.0158	0.0162	0.0166	0.0170	0.0174	0.0179
–2.0	0.0183	0.0188	0.0192	0.0197	0.0202	0.0207	0.0212	0.0217	0.0222	0.0228
–1.9	0.0233	0.0239	0.0244	0.0250	0.0256	0.0262	0.0268	0.0274	0.0281	0.0287
–1.8	0.0294	0.0301	0.0307	0.0314	0.0322	0.0329	0.0336	0.0344	0.0351	0.0359
–1.7	0.0367	0.0375	0.0384	0.0392	0.0401	0.0409	0.0418	0.0427	0.0436	0.0446
–1.6	0.0455	0.0465	0.0475	0.0485	0.0495	0.0505	0.0516	0.0526	0.0537	0.0548
–1.5	0.0559	0.0571	0.0582	0.0594	0.0606	0.0618	0.0630	0.0643	0.0655	0.0668
–1.4	0.0681	0.0694	0.0708	0.0721	0.0735	0.0749	0.0764	0.0778	0.0793	0.0808
–1.3	0.0823	0.0838	0.0853	0.0869	0.0885	0.0901	0.0918	0.0934	0.0951	0.0968
–1.2	0.0985	0.1003	0.1020	0.1038	0.1056	0.1075	0.1093	0.1112	0.1131	0.1151
–1.1	0.1170	0.1190	0.1210	0.1230	0.1251	0.1271	0.1292	0.1314	0.1335	0.1357
–1.0	0.1379	0.1401	0.1423	0.1446	0.1469	0.1492	0.1515	0.1539	0.1562	0.1587
–0.9	0.1611	0.1635	0.1660	0.1685	0.1711	0.1736	0.1762	0.1788	0.1814	0.1841
–0.8	0.1867	0.1894	0.1922	0.1949	0.1977	0.2005	0.2033	0.2061	0.2090	0.2119
–0.7	0.2148	0.2177	0.2206	0.2236	0.2266	0.2296	0.2327	0.2358	0.2389	0.2420
–0.6	0.2451	0.2483	0.2514	0.2546	0.2578	0.2611	0.2643	0.2676	0.2709	0.2743
–0.5	0.2776	0.2810	0.2843	0.2877	0.2912	0.2946	0.2981	0.3015	0.3050	0.3085
–0.4	0.3121	0.3156	0.3192	0.3228	0.3264	0.3300	0.3336	0.3372	0.3409	0.3446
–0.3	0.3483	0.3520	0.3557	0.3594	0.3632	0.3669	0.3707	0.3745	0.3783	0.3821
–0.2	0.3859	0.3897	0.3936	0.3974	0.4013	0.4052	0.4090	0.4129	0.4168	0.4207
–0.1	0.4247	0.4286	0.4325	0.4364	0.4404	0.4443	0.4483	0.4522	0.4562	0.4602
–0.0	0.4641	0.4681	0.4721	0.4761	0.4801	0.4840	0.4880	0.4920	0.4960	0.5000

z	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998